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foreword

Fiscal year 1979 has been a successful year for the research and development program at the Harry Diamond Laboratories (HDL), marked by significant technological achievements, production and fielding of new equipment, and the continued pursuit of an aggressive development program.

In FY79, major laboratory accomplishments in the electronic fuzing area contributed importantly to the Army's materiel readiness. The M735 fuze for the 8-in. nuclear projectile was type classified and its first production contract was awarded. Also entering first production was the M587/M724/M36 electronic time fuze system. The $77M contract awarded for the initial production quantities of this fuze and setter is the largest multi-year contract ever awarded by HDL. HDL fulfilled its development support role for the M732 fuze, with delivery of 219,000 first production units.

This laboratory's development program recorded substantial progress. Work on the XM818 fuze for the Patriot missile progresses toward the production engineering phase. HDL supported the Patriot Project Manager in flight testing by providing fuzes, test equipment, and postflight analysis. A lightweight, hand-cranked generator was developed to meet a Special Forces requirement for a highly portable power source for field radios. Also, HDL initiated a program to develop a tactical shelter with improved hardness against nuclear and conventional weapons effects.

Continued research in the radar, fluidics, and acousto-optics fields produced important breakthroughs and innovative military hardware applications. As ERADCOM's center for radar technology, HDL initiated a technology base program that included initial investigations of multistatic battlefield surveillance and target-acquisition radars for defense against anti-radiation missiles. The feasibility of applying advanced digital techniques to FM radar fuze systems was demonstrated in FY79. HDL began testing and evaluation of the Installation Security Radar in 1979, and developed a target classification system for use with this radar. The fluidics research team successfully demonstrated a fluidic tank turret stabilization system, and the acousto-optics group continued work on several acousto-optic signal-processing devices—key components of new, more efficient radar and communication signals location and identification systems.

Finally, the Assistant Secretary of the Army again accorded HDL top honors among all Army research and development laboratories for its FY79 Independent Laboratory In-House Research (ILIR) program. Principal ILIR projects included research in surface-acoustic-wave signal processes and the development of a new reflex ion triode and devices for subaural acoustic signal detection and processing.

Entering a new decade of greater challenges, HDL looks forward to serving as a major contributor to this nations's military preparedness, through the development and exploitation of technologically superior weapons systems.

Clifford R. Goodwin
Colonel, AD
Commanding

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chapter 1. executive summary

The Harry Diamond Laboratories, one of the major scientific establishments of the US Army Materiel Development and Readiness Command (DARCOM), is a complex of diverse facilities, with a staff having a broad competence in research, development, and engineering. When HDL was first established as an Army laboratory in 1953, its investigations were focused primarily on ordnance fuzes and related technologies. In 1962, as a result of a major Department of the Army (DA) reorganization, HDL was given a broader mission and assigned to the Army Materiel Command (AMC—now DARCOM); HDL reported directly to the Deputy Commanding General for Materiel Development. On 20 March 1977, the US Army Electronics Research and Development Command (ERADCOM) was assigned operational control of the Laboratories.

This second year as part of ERADCOM was a year of reevaluation and adjustment, as HDL sought, on the one hand, to maintain its national reputation for excellence in its traditional areas of expertise (fuzing, nuclear weapons effects, fluidics) and, on the other hand, to apply its talents to the solution of problems in ERADCOM's mission areas (radar, near-millimeter-wave technology, electronic warfare, and so on). This diversification of technical programs coincided with a significant reduction of laboratory personnel strength. During FY79, HDL lost an important number of technical personnel because of retirements, the high-grade promotion freeze, and competition from industry and other government agencies for young engineers and scientists. This loss of technical personnel is expected to continue throughout FY80.

During FY80, HDL capabilities must be reexamined by ERADCOM and HDL, to determine the extent and nature of its future mission in Army electronics. A strong staff of technical personnel will remain, but they are being severely taxed to properly handle the ongoing research, development, engineering, and initial production tasks.

Noteworthy Technical Contributions.

Fuzing.

XM445 GSRS Fuze. The fuze for the General Support Rocket System (GSRS) has completed its Engineering Development Tests (EDT-C) and is ready to start Advanced Development and Verification Tests (ADVT-C and ADVT-G) and Operational Tests (OT-I) in preparation for the Army Systems Acquisition Review Council (ASARC) which is scheduled for early 1980.

XM818E1 Fuze for Patriot. During 1979, the Engineering Design (ED) and Production Engineering Planning (PEP) programs have combined to refine the XM818E1 fuze design, improve the reliability of the major components or subassemblies, and develop automated test equipment compatible with the fuze design and the production rates. DT/OT-II flight tests are being conducted with fuzes that

contain a new high-reliability transmitter, hybrid microcircuits, and a single large-scale integrated logic element that performs most signal-processing functions. Fuze-target and fuze-jammer encounter models have been developed to complement flight tests for assessment of the kill probability of the Patriot system. An Initial Production Facility (IPF) program has been initiated to fabricate production tooling and automated test equipment.

M735 Fuze for 8-in. Nuclear Projectile. In DT-II testing of the M735 fuze, 149 of the required 154 fuze firings were successfully completed, with no system or safety failures. The last five fuzes will be tested after completion of projectile container tests by the Armament Research and Development Command (ARRADCOM). The first procurement contract, for 155 fuzes and 50 telemeters, was let. The XM38 setter for the fuze will be type classified and procured in FY80.

M587/M724/M36 Electronic Time Fuze System. After a highly successful DT-II/OT-II program, during which very high reliability and accuracy were demonstrated, the M587/M724/M36 system was type classified in January 1979. Contracts were then awarded for the initial production and design of manufacturing facilities for the M587/M724/M36 system. PIP (product improvement program) efforts are now under way to further reduce the cost of the fuze. A new fuze setter, using microprocessor technology, is being developed which will reduce both the size and cost of the fuze.

Digital Fuzing Techniques. Advanced new digital techniques are being used in FM systems, that, for the first time, eliminate dependence on generating reference signals from real-time waveforms. This provides the fuze designer with an additional degree of freedom and a new dimension of system performance. The ability to digitally synthesize highly complex modulation and mixer reference waveforms allows generation of heretofore unavailable range discrimination and improved electronic counter-countermeasure performance. These techniques use proven integrated-circuit processing methods and may be implemented using small, reliable large-scale integrated circuits. Feasibility has been demonstrated by laboratory tests of ground-target FM radar fuzes for 200- to 2000-ft function heights and in an air-target fuze for a 20-ft miss distance.

M734 Multi-Option Mortar Fuze. The M734 multi-option mortar fuze for the Lightweight Company Mortar System was put into production.

DIVADS Fuze Analysis. HDL is supporting the DIVAD (Division Air Defense) Project Manager by providing a major input to the DIVAD Gun System selection process. Through the use of 1/5 scale target models and complex FM radar probes especially designed to represent the fuze rf transceiver, Doppler signatures for 500 trajectories for each of three targets have been obtained at the Naval Weapons Center Model Range facility. The fuze burst positions, generated by processing trajectory signatures in a validated computer model of the fuze processor, will be used by the US Army Materiel Systems Analysis Activity (AMSAA) as part of an overall system lethality study. This same information will be used by the competing firms to evaluate and improve their systems' performance.

Nuclear Weapons Effects (NWE). HDL has continued to support the SINCGARS PM's NWE survivability program through a DNA-funded effort and to support 26 materiel development projects through the Nuclear Effects Support Team (NEST).

EMP survivability analysis and testing of the Tactical Fire Direction (TACFIRE) system was completed at the Woodbridge Research Facility of HDL. Definitive results have been obtained through the use of computer-augmented circuit analysis and experiments conducted at the Army EMP Simulator Operation (AESOP).

A program has been initiated to develop a hardened tactical shelter (HATS) which will have improved survivability to NWE and conventional fragments, and provide collective protection. It is expected to replace the present S-280 and S-250 electronic equipment shelters.

Fluidics. The most significant event in the fluidics area in 1979 was the successful demonstration of

the stabilization of the main gun on an armored combat vehicle. The fluidic turret stabilization system has greater ruggedness, higher reliability, and lower initial and life-cycle costs than electromechanical systems can offer.

The stabilization program used laminar-flow devices (the second generation of fluidic componentry), for the first time. An active research program on these devices is also being conducted in support of this and other development programs. Laminar-flow devices have the potential for orders of magnitude improvement in dynamic range and sensitivity over the first-generation turbulent-flow devices. As a result of this research and the work done in the stabilization program, a new program was initiated in 1979 to develop a fluidic heading reference unit for armored vehicles.

Surveillance and Target Acquisition. The new HDL program in radar technology was a natural outgrowth of HDL's many years of involvement in foreign and special-purpose radars. This year a task was initiated to develop the technology of multistatic battlefield surveillance and target-acquisition radar. Such radars are felt to be necessary for defense against attacks by anti-radiation missiles.

Several tasks related to installation security have also been under way at HDL. The Installation Security Radar (ISR) program delivered one unit to the Pantex Plant in Amarillo, TX, and is now evaluating the ISR's performance jointly with Sandia Laboratories. A system to classify targets that can separate threat, nuisance, and false targets has been developed for use with the ISR. A program to develop an optical intrusion detector was also undertaken, with one system built and installed for testing at Yuma Proving Ground.

Devices and Technology. The program on acousto-optic signal processing, a basic technology program begun at HDL several years ago, has yielded a steady stream of devices that can perform extremely sophisticated signal-processing functions faster and cheaper than more conventional techniques. Work continued this year on three tasks, all related to the basic problem of more efficient analysis of radar and communication signals. These tasks were the development of a time-integrating correlator, a triple-product convolver, and a memory correlator. In particular, the time-integrating correlator provides about 50 dB of processing gain. It has been shown to provide simultaneously the center frequency, bandwidth, and relative time-difference-of-arrival of radar and communications signals.

Penetration of Obscurants.

Solid-State NMMW Source Theory. FY79 marked the beginning of a theoretical effort directed at finding solid-state NMMW sources centered around periodic structures, both naturally occurring and man-made. A calculation was begun on the general problem of threshold gain for laser action in a structure consisting of alternating layers of active and passive material; this calculation revealed that size constraints on a passive waveguide structure (that is, 1-mm radiation cannot propagate in a 1-µm channel) need not hold if the guide is filled with active-passive layers. This discovery indicated that even a small superlattice structure with gain in the NMMW region could lase, despite its size.

Ultra-High-Resolution Spectroscopy. A diode laser heterodyne spectrometer has been constructed for wideband (13-GHz), rapid, and accurate (6 MHz in 30 THz) measurement of infrared absorptions. Data taken on 1,1-difluoroethylene ($F_2C{=}CH_2$) has permitted the calculation of molecular constants, the modeling of the NMMW source, and the prediction of new NMMW emissions.

Signals Warfare.

Unattended/Expendable Jammer (UEJ). HDL continued its work on the development of the UEJ, which is designed to be delivered in large numbers by artillery rounds and to disrupt and confuse the enemy's tactical communications. During FY79, progress was made on the power supply, antennas, and dispersion technique—all critical areas.

In-House Laboratory Independent Research (ILIR). HDL received one of the top scores in the Army for its ILIR program in FY79. ILIR contribu-

tions include a new surface-acoustic-wave signal-processing device (a triple-product convolver), a new reflex ion triode that generated over 4 GW of rf energy at X band, over 25 new laser lines in the near-millimeter-wave spectrum identified in optically pumped lasers, fluidic devices for subaural acoustic signal transmission and processing, and a new technique to simulate electrically the effects of ionizing radiation in MIS (metal insulator semiconductor) gate insulators.

Other Technical Highlights.

Fuzing.

Anti-Armor Fuzing. The design of an inductive proximity sensor was completed for the 106-mm HEAT round. Eight rounds were test fired, and standoff detonation was successfully demonstrated.

Fuze for Shoulder-Launched Multipurpose Assault Weapon (SMAW). HDL is developing the fuze for SMAW, a Marine Corps weapon. Fuzes supplied for advanced-development field tests diring FY79 met all the major performance requirements.

XM749 Fuze for 155-mm Nuclear Projectile. The XM749 fuze was phased into engineering development during FY79 after a baseline volume and electrical interface was established between DoD and the Department of Energy, the warhead developer. A contract has been let to develop the fuze circuitry and packaging.

M732 Fuze. With the delivery of the first batch of production fuzes (219,000 units) HDL's role in the successful M732 fuze program has changed to that of providing engineering support as required, after transition to the Armament Materiel Readiness Command.

M734 Multi-Option Fuze for Mortars. The development of a practice fuze (XM745) for the M734 was begun during 1979. Also, plans have been made to type classify the M734 on the UK 81-mm mortar during FY80. Meanwhile, procurement of the basic fuze for the 60-mm mortar is proceeding in parallel with fabrication of an initial production facility. Initial deliveries have been delayed several months by supply and startup problems.

Fuze Exploratory Development Program. As it has for many years, HDL continued its various applied research programs to support the fuzing technology base. The program consisted of a wide variety of tasks spanning such diverse areas as target sensing, signal processing, counter-countermeasure techniques, power supplies, safety and arming mechanisms, componentry, materials research, simulation, and advanced design techniques. This entire program has the single goal of pushing forward the state of the art in fuzing for all types of munitions. Many of the fuzes currently in production, or about to go into production, were first conceived in this highly productive technology base program.

Roland Fuze Support. In response to the Roland Project Manager, HDL has executed a laboratory effort to evaluate the performance of the Roland fuze and to investigate design modifications (such as the important fuze delay algorithm) which promise improved performance. The results have been presented to and accepted by the three national governments concerned. The analytical work has been validated by experimental laboratory measurements. Fuze system changes, based upon the proposed design modifications, form the basis of a pending improvement program.

Surface Proximity Fuze (SPF). The surface proximity fuze program, being carried out for the Air Force, requires state-of-the-art fuzing technology. In FY79, three possible approaches to this extremely difficult problem were narrowed to one preferred method. Procurement of prototype transmitters and receivers was initiated. A request for proposals (RFP) was completed for the flight testing of several complete fuzes.

Fuze Encounter Simulation. A radar-fuze/air-target encounter simulation was developed for the Patriot project office. This simulation will become part of the overall Patriot system simulation, and will be used to verify Patriot system performance. The fuzing simulation includes near-field radar reflectivity models of three different targets suitable for describing fuze-target interaction, and models of the Patriot fuzing signal processor and logic circuits. The simulation, which can handle an ECM environ-

ment and formations of up to 10 targets, is the most comprehensive ever undertaken for fuzing. The computer models have been validated through velocity-scaled tests at HDL's Blossom Point facility.

Nuclear Weapons Effects. As the DARCOM lead laboratory for NWE research and testing, HDL is heavily engaged in (1) system vulnerability assessment and hardening for DARCOM Project/Program Managers and Commands, the Defense Nuclear Agency, and the Defense Communications Agency; (2) technology development and application associated with nuclear weapon electromagnetic pulse (EMP), system-generated EMP (SGEMP), transient-radiation effects (TRE), and blast and thermal effects; (3) research development and operation of EMP, TRE, thermal radiation, and blast simulators; (4) NWE information dissemination; and (5) tactical nuclear warfare studies.

Vulnerability Assessment/Hardening. In FY79, the NWE program continued to emphasize the vulnerability assessment and hardening studies of both tactical and strategic communications, command, and control (C^3) systems. High-altitude EMP (HEMP) vulnerability studies were conducted for the Tactical Fire Direction (TACFIRE) system. Initial hardening concepts for a high-capacity multichannel communication system were generated, and tests were performed on the AN/TRC-122 troposcatter multichannel radio terminal. An analysis of the siliconized version of the AN/VRC-12 single-channel radio was completed on short notice and had significant impact on a major product improvement program (PIP). DT-II EMP tests were performed on the XM-1 tank. A candidate 150-kW turbine generator for the Patriot system was also successfully tested in the EMP simulation facility. Extensive analytical and scale-modeling studies were performed in preparation for the Patriot Fire Unit, to be conducted in FY80.

TRE studies have been completed for a number of single-channel and multichannel communications systems, assessments completed for the AN/MPQ-4A and AN/PPS-5 target-acquisition radars, and studies initiated on the AN/VPS-2 and AN/TPS-58 radars.

Significant advances have been made in the development of information on the susceptibility of semiconductor components to the effects of EMP and radiation.

HEMP Survivability of Defense Communication System (DCS). HDL has continued to support the hardening of future DCS systems through the development of a HEMP Design Practice Handbook. Plans for verifying and evaluating high-priority design practices were developed, as were HEMP specifications for hardening applications.

A study of HEMP effects on Defense Satellite Communications System terminals was completed. Four proposed AUTODIN II sites have been surveyed for good HEMP practices.

Simulators. All NWE simulators have been extensively used during the fiscal year, and many strategic and tactical system developers were supported in their NWE efforts. The new high-intensity electron-beam capability of the AURORA facility was successfully used to support a DNA materials program.

Tactical Nuclear Warfare Studies. In support of the Army Theater Nuclear Forces Survivability (TNF/S) program, HDL provided survivability evaluations for selected Lance Firing Battery configurations, critical nuclear release radios, and vehicles organic to mobile special ammunition supply points. In addition, computer models simulating the European Army Communications Networks were developed or modified to investigate the impact on combat effectiveness of the degradation of C^3 on the nuclear battlefield.

HDL assisted DoD in the development of a program to increase the HEMP survivability of existing nuclear weapons support sites.

Fluidics. As DARCOM's Lead Laboratory for fluidic technology, HDL continues to provide a focal point for work in this field, not only in the Army, but

throughout DoD. This technology provides alternative methods of performing various control and logic functions in environments where the use of electronics is not appropriate.

One development this year, the fluidic resistance thermometer, has great potential in continuous meaurements for high-temperature process controls. Use of this sensor (in, for example, high-temperature furnaces employed in basic metal fabrication) will save considerable energy and increase the quality of products. The National Bureau of Standards is considering this device as the primary temperature standard above 1700°F.

A number of other systems applications were developed to various stages during 1979. Among them were a fuel control for a gas-turbine engine, a variable shock absorber for military vehicles, a fluidic limited-slip differential mechanism (also for vehicles), an autopilot wing leveler for drone aircraft, and a variety of components and manufacturing techniques. From the long-term view, however, the most important accomplishment was probably the research into the characteristics of the new laminar-flow technology, from which whole new families of devices are expected to evolve over the next few years.

Devices and Technology.

Acousto-Photorefractive Memory Correlator. The storage mechanism for the writing geometry using infrared (1064-mm) laser light has been determined to be purely a storage of charge on the surface of $LiNbO_3$. Storage at 1064-nm has been characterized using scanning electron microscopy, photoconductivity and photovoltage measurements, and electrostatic probes.

Triple-Product Convolver (TPC). The TPC has been constructed using discrete lasers and detectors. An 8-pt discrete Fourier transform has been performed with the TPC, and a signal-to-noise ratio of 50 dB was obtained.

Acousto-Optic Interaction Theory. A theory has been formulated that postulates a new type of electron trap to account for the peculiar transport effects of lithium niobate ($LiNbO_3$). This theory has explained several anomalous optical phenomena in $LiNbO_3$ and has identified the storage mechanism as a John-Teller shift in the electronic structure created by light.

Penetration of Obscurants.

Near-Millimeter-Wave (NMMW) Technology. NMMW technology offers a potential solution to the problem of conducting operations in a limited-visibility environment. HDL continued to build a varied and diverse program in this new technology: programs in sources of all types (solid state, tube, and molecular gas), detectors, components, measurements, and preliminary systems concepts were undertaken. HDL continued in its role as ERADCOM coordinator of NMMW programs; HDL's worldwide leadership in the field was demonstrated by the fact that an HDL employee was invited to deliver the keynote address at the Fourth International Conference on Infrared and Millimeter Waves.

NMMW Oscillator. NMMW laser emission was achieved in a new medium, fully deuterated methyl fluoride (CD_3F). Sixteen lines between 0.15 and 1.5 mm have been observed. Laser emission has also been observed for the first time in chlorodifluoromethane ($CHClF_2$), and ethyl iodide (C_2H_5I).

Pulsed NMMW Sources. Kilowatt output emission has been obtained at 0.5 and 1.2 mm from an unstable resonator. The pulsed output was used to calibrate accurately the pulse energy response of Golay, calorimeter, and pyroelectric detectors.

Theory of NMMW Orotrons. A computer program has been written to calculate the electromagnetic field when a plane electromagnetic wave impinges on a reflecting diffraction grating of rectangular cross section. Theory has been worked out that uses these results to predict starting currents and frequency characteristics of orotrons, which are tunable sources of electromagnetic radiation employing an electron beam, diffraction grating, and an open resonator.

Investigation of Solid-State NMMW Source. An extensive literature search has been completed in order to find an appropriate material which contains rare-earth ions, for submillimeter-wave generation. The material $Cs_2NaLnCl_6$ seems to be a favorable material for a complete theoretical investigation.

Technical Achievements Leading to Dollar Savings. Significant reductions in the procurement costs of the recently type classified M587/M724/M36 electronic time (ET) fuze system are expected to result from the successful completion of certain ongoing programs. Manufacturing methods and technology (MM&T) activities sponsored by the Project Manager for Production Base Modernization and Expansion have developed techniques that should reduce the cost of the special integrated circuits (IC's) used in the M587 and M724 ET fuzes. By increased integration and the application of high-volume manufacturing techniques, the procurement cost of these special-purpose IC's will be reduced by approximately $20 per set. With planned procurements of 500,000 fuzes per year, savings should amount to $10,000,000 per year.

The M36 fuze setter is scheduled for replacement by the M36E1 fuze setter which is currently in engineering development and employs microprocessor technology instead of large numbers of individual IC's. The development will not only reduce the physical size and weight of the setter but should halve the procurement cost, saving $1500 per setter or, considering planned procurement figures of 2000 setters per year, $3,000,000 per year.

Noteworthy Technical Management Actions. HDL management, with ERADCOM support, made the commitment to undertake the advanced development of the sensor for the Anti-Radiation Projectile (ARP) in support of the Project Manager for Cannon Artillery Weapons Systems (PM-CAWS). In order to staff this new, high-visibility, high-technology program, HDL had to relinquish instrumentation development for the Operational Test and Evaluation Agency and technology support to the Project Manager for Training Devices.

In response to a directed manpower reduction, HDL management reluctantly decided to withdraw its support of the Air Force's ABRES (Advanced Ballistic Reentry Systems) program, specifically the exploratory development of the surface proximity fuze. The Air Force's protest against this action caused the Directorate for Defense Research and Engineering to request the Army to review this decision. The result was that the program decision was reversed, although the personnel cut remained.

HDL management decided that (with additional funds from ERADCOM) a portion of the acousto-optic research program should be directed toward a field demonstration of the utility of the new techniques for the collection of ELINT (electronic intelligence).

In order to meet critical needs for the development of shelters hardened to nuclear and conventional weapons effects, HDL established a Hardened Tactical Shelter (HATS) project office within HDL, drawing on existing resources. Concentrated management of this program was determined to be necessary to meet severe schedule constraints.

HDL management decided to terminate HDL activities concerning mine fuzing. Loss of key personnel, dwindling financial support, and the inability to affect Army mine fuze programs were all contributing factors to this decision. As a result, the Magnetic Latitude Simulation Facility, which HDL constructed and operated at Aberdeen Proving Ground, will be transferred to the Large Caliber Weapons Systems Laboratory, of ARRADCOM.

The dismantling of the Diamond Ordnance Radiation Facility reactor, which is in its final stages, will be completed in June of 1980. The final disposition of this facility will allow a more efficient use of allocated funds and personnel for higher priority and more critical projects.

Nuclear Effects Support Teams were established to provide NWE expertise to several dozen Army developers.

Effort in the fluidics area was redirected by the initiation of the project on the fluidic heading reference unit.

Administrative Highlights. After last year's major realignment of the organizational structure, the changes occurring in 1979 were, for the most part, of a "fine tuning" nature. The most significant change took place when the Administrative Support Office (except for the Travel and Transportation branch) was combined with the Technical and Visual Information Office. This consolidated office, called the Technical Information and Administrative Office, now reports directly to the Command Group. The current organization of HDL is shown in figure 1.

HDL management also decided to merge the Budget Branch of the Comptroller's Office with the Program and Plans Office; the new entity will be called the Plans and Operations Office. The effect of this change will be to increase the efficiency with which day-to-day administration of the laboratories' technical program is accomplished. This change will be implemented in early FY80.

Major Program Structure. During fiscal year 1979, HDL continued its major efforts in the development of fuzes for Army, Navy, and Air Force weapons such as Patriot, GSRS, nuclear artillery, Sea Gnat, and the MX missile. In addition, HDL continued to support ERADCOM's electronic warfare mission through the development of an artillery-delivered, expendable, communications jammer. HDL is also developing a state-of-the-art sensor for the Army's Anti-Radiation Projectile (ARP), for PM-CAWS, ARRADCOM. Also during FY79, HDL was given ERADCOM responsiblity for Personnel and Vehicle Detection Radar Technology and began a major program to develop a Hardened Tactical Shelter (HATS).

As a full-spectrum laboratory, HDL is concerned with all phases of research, development, engineering, initial production, and procurement. HDL sponsors are the major military commands, including DARCOM commodity commands and project managers, the Defense Nuclear Agency (DNA), the Defense Communications Agency (DCA), the Air Force, the Navy, and some non-DoD federal agencies. Although most of HDL's projects are customer funded, nearly $16 million was received in FY79 via ERADCOM from DARCOM Headquarters. These funds support basic research and exploratory and advanced development which form the cornerstone of HDL's technical capabilities. Projects in this category include A91A (Independent Laboratory In-house Research—ILIR), the single project funded (SPF) AH44 (Research in Fluidics, Nuclear Effects, and Ordnance Electronics), the single program element funded (SPEF) AH25 (Nuclear Weapon Effects, Fluidics, Near-Millimeter Wave Technology), D181 (Anti-Radiation Missile Countermeasures), and D153 (Nuclear Effects Support Team). HDL's major contribution to electronic fuze technology is executed with funding provided by ARRADCOM under project AH18.

Figure 2 shows the total HDL program divided into individual commodity areas oriented toward intelligence, surveillance, and target-acquisition (ISTA). This program structure serves as the basis for describing and managing HDL's activities and is also used as a means for organizing this report. HDL's involvement in each of these commodity areas is described below.

Fuzing. HDL is concerned with the development and initial production of fuzes for both conventional and nuclear projectiles and missiles. HDL has a comprehensive program in fuzing technology, including investigations of target-sensing systems, electronic technology, materials, power supplies, safety and arming mechanisms, and various testing, instrumentation, simulation, and data-acquisition techniques.

Nuclear Weapons Effects. The nuclear weapons area includes systems analysis and hardening of electronic material to survive thermal effects, transient-radiation effects, blast and shock effects, and the effects of both internal and external electromagnetic fields. Also, HDL is developing the Army's HATS.

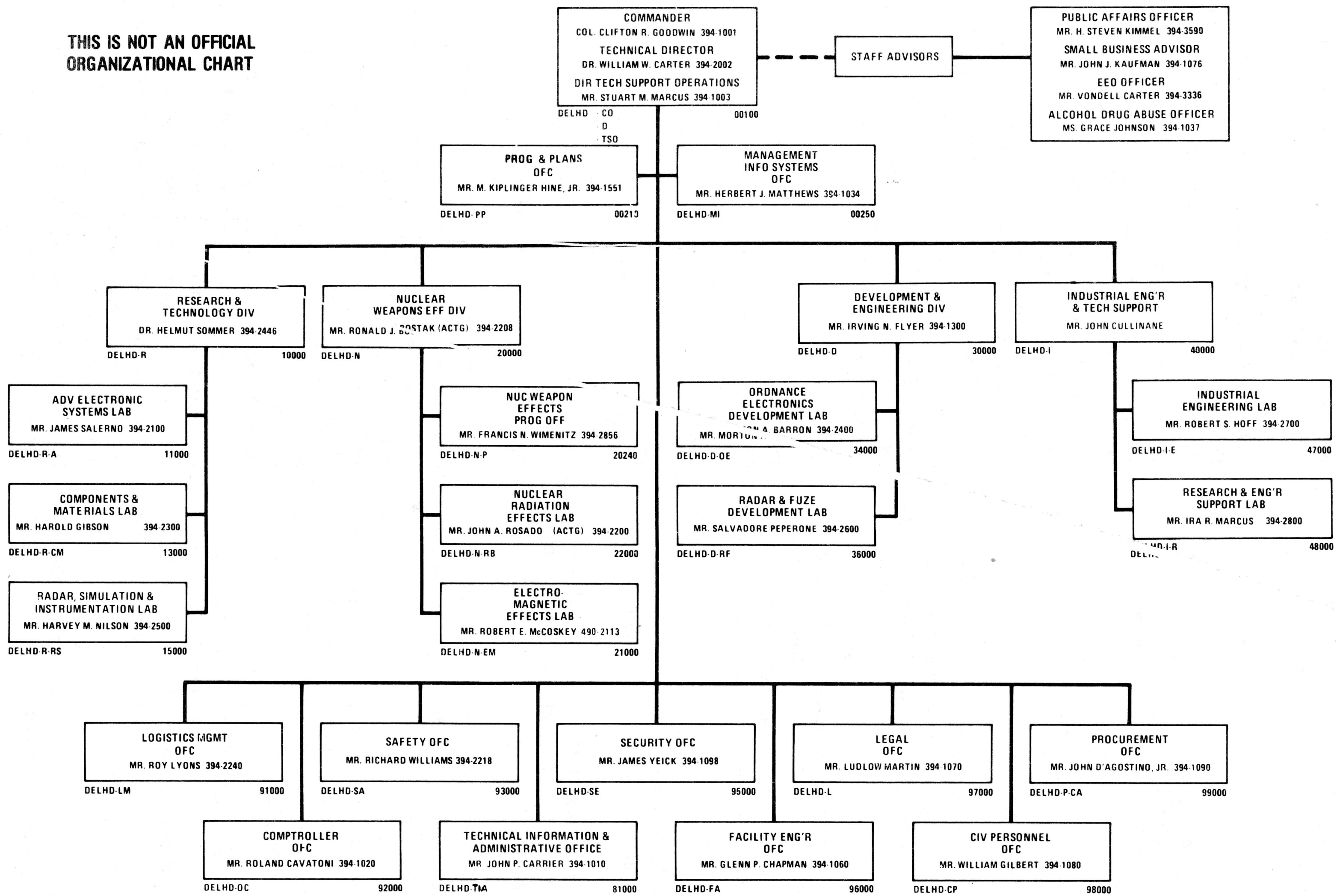


Figure 1. Organizational chart for HDL, FY79.

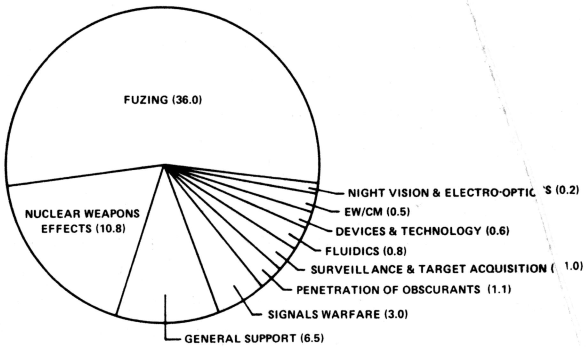


Figure 2. HDL program structure.

Fluidics. HDL's fluidics program concentrates on development and application of fluidic technology for use in ordnance, control systems, and instrumentation.

Surveillance and Target Acquisition. This area includes the Personnel and Vehicle Detection Radar Technology Base, as well as applications for physical site security and the simulation of foreign air-defense systems.

Devices and Technology. HDL researches acousto-optic devices and other electronic components.

Electro-Optics. HDL performs basic research in low-energy lasers and research and development relating to laser-guided weapons.

Penetration of Obscurants. This area includes basic and exploratory development of near-millimeter-wave technology.

Electronic Warfare. HDL's electronic warfare program includes management of, and technical contributions to, the Army's Anti-Radiation Missile Countermeasures program.

Signals Warfare. HDL's efforts in this area include advanced development and technical support of a family of unattended, expendable communications jammers and development of the sensor for the Anti-Radiation Projectile.

General Support. A variety of projects are classed as general support, including instrumentation, training aids, computer-aided design, environmental simulation and testing, and so on.

Personnel and Manpower. The number of full-time permanent civilian employees at the end of FY79 was 1096, a decline from the end of FY78 (1141). Not included in the above count are 14 HDL employees who are supporting the Signals Warfare Laboratory at Vint Hill Farms Station, VA; nor does it include 166 Headquarters ERADCOM employees, 50 DARCOM Personnel Support Agency employees, 9 US Army Communication Command employees, and 12 BETA employees, who are also located at Adelphi, MD. Figure 3 shows the total civilian strength at HDL for FY79, including full-time permanent employees, part-time or temporary employees, and the 14 HDL employees at Vint Hill.

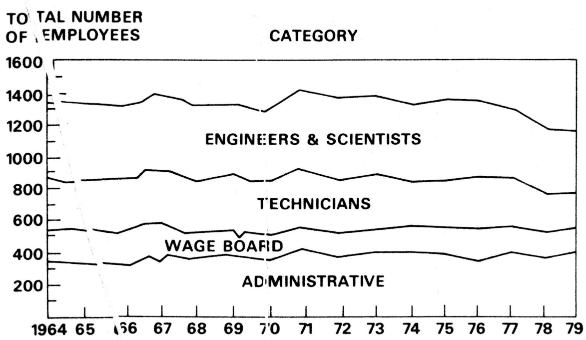


Figure 3. Civilian strength at HDL, FY79.

The average grade of HDL employees at the end of the last three fiscal years in shown in table 1. HDL sustained a net loss of 45 full-time employees during the year, but these employees represented such a span of grades that their loss did not materially affect the average grade. The slight change in grade does not, however, necessarily reflect a stabilized situation in FY79. Because of quota limitations on high grade positions (GS-13 through GS-15), very few promotions were made to those grades compared with potential requirements and past practice. These figures are also misleading because of the continuing high number of professional scientific and engineering positions, GS-9 through GS-11, remaining unfillable. Average grade control will be appropriately managed by the Commander and Technical Director and their staff to assure that the

assigned average grade for HDL (10.316) is not exceeded in FY80.

Table 1. Average Grade Calculation

Category	30 Sep 77	30 Sep 78	30 Sep 79
Full-time, permanent	10.1802	10.1363	10.1411
Full-time, permanent and temporary	10.0685	10.0354	9.9704

Individual contributions to scientific technology continued as in previous years, as revealed by reports, presentations, patents, and performance awards (see table 2).

Table 2. Activity Indicators

External publications	62
Internal publications	74
Professional presentations	89
Invention disclosures	44
Patent applications	33
Patents issued	35
Civilian personnel OPR	14
Civilian personnel SSP	27
Civilian personnel QSI	17

Equal Employment Opportunity (EEO) Program. Various factors this year were unfavorable to the EEO program. The overall number of employees at HDL decreased during FY79, thereby causing a loss of minorities and women in the workforce; further, the positions left vacant by the departure of the Federal Women's Program Manager (FWPM) and the Hispanic Employment Program Manager (HEPM) created some setbacks in the Equal Employment Opportunity Program. Despite these disadvantages, some measurable progess was made. (a) Five Upward Mobilty Program (UMP) positions were identified and are presently being filled. The UMP panel, consisting of HDL employees, was instrumental in making recommendations to management in filling these positions. (b) Cultural awareness activities were well attended by the HDL workforce. (c) Additional staffing of the EEO office was authorized, and identified positions are expected to be filled by the end of 1979. (d) New members drawn from the HDL workforce joined the FWP council.

Program emphasis on the recruitment of women and minorities into the engineering and sciences (E&S) career fields is still required. The Student Trainee Program includes 20 undergraduates in the E&S field (including three women and one minority). During 1979, 16 student trainees were hired and four current student trainees returned to HDL during the summer. Participation in the Armed Forces Orientation to Engineering Careers (AFOTEC) and the Pre-Freshman and Cooperative Education (PREFACE) programs is seen by the Command as a means of attracting greater numbers of minority and female high school students to federal careers in E&S. Four minority members were among the 18 students selected for the 79/80 Vocational Opportunity Training (VOT) Program. Two of the minority students are employed in the EEO office and the Command Headquarters.

All the above are positive trends and demonstrate the increased awareness and support of the EEO program by HDL managers and supervisors.

Funding and Expenditures. HDL finances its operations through the Army Industrial Fund (AIF). HDL was originally chartered by the Assistant Secretary of Defense (Comptroller) on 21 October 1953. Subsequently, a single Army Industrial Fund Charter for the US Army Materiel Development and Readiness Command (DARCOM) Industrial and Commercial-Type Activities was issued on 3 August 1962. Those customer orders not meeting the criteria for financing by AIF are financed on an appropriation basis referred to as Non-Army Industrial Fund (NAIF). Currently, HDL's AIF cash allocation is $1,929,000; HDL replenishes this fund monthly by billing those customer orders which have incurred expenditures.

Funding. For FY79, HDL's total obligational authority (TOA) was $189.2 million, of which $60.6 million (32 percent) was programmed for in-house

(AIF) expenditures and $128.6 million for out-of-house (NAIF) efforts by other government agencies and contractors (see fig. 4 for breakdown of TOA).

TOA CATEGORY ($K)		
AIF		$ 60,568
NAIF		$ 128,593
OMA	$ 25,736	
PROC	$ 77,768	
RDTE	$ 25,089	
TOTAL		$ 189,161

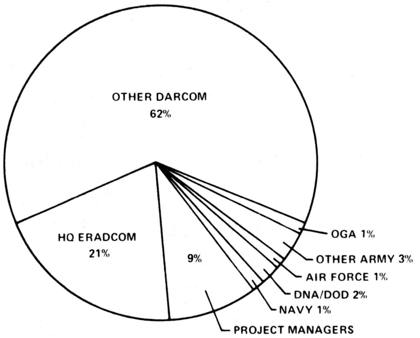


Figure 4. Breakdown of HDL's total obligational authority.

Funds received in FY79 (excluding carryover funds from prior years) amounted to $181.3 million. Of the total, $172.9 million was financed by Army appropriations, with the balance of $8.4 million provided by other DoD and federal agencies. Table 3 gives details of HDL's income.

In the FY78 report, $20 million of OMA (operations and maintenance, Army) funds for the DARCOM Career Intern Program was listed as direct funding from HQ, DARCOM. This year, these funds ($23.1 million provided by the Personnel Support Agency, DARCOM) are listed as "Other DARCOM" funds. Also note that HDL received $24 million of pass-through funds. These two categories of income account for about $47 million of HDL's TOA, although neither support the HDL mission. These changes significantly alter the pie-chart distribution in figure 4. However, the total of "Other DARCOM" and "HQ ERADCOM" is almost the same as FY78, indicating a relatively constant emphasis on DARCOM work.

Execution. Total obligations of $164.6 million were recorded in FY79. Expenditures for the year were $162.9 million, of which $56.9 million (35 percent) was AIF and $106.0 million was NAIF (see tables 4 and 5).

The largest in-house (AIF) expenditure (see tables 5 and 6) was for salaries and wages (55 percent). This represented 1172 man years of effort with an average salary of $26,284 per man year. Of the total man years, 516 (44 percent) were direct-labor man years and 656 (56 percent) were indirect (indirect man years are those in technical support services, laboratory supervision, and general and administrative support areas). Table 7 shows the distribution of man years, profile of personnel, and workforce strength. Total expenditures in these areas represent HDL's operating and administrative overhead costs, which are distributed back to customer orders on the basis of a fixed charge per direct-labor hour. HDL's total overhead costs were $19.7 million, or 122 percent of direct-labor dollars. The largest category of expenditure was for contractual services in support of in-house effort—$17.5 million, or 31 percent of the total AIF expenditures.

Table 3. HDL Income during FY79

DARCOM Source	$K
HQ, ERADCOM	31,787
HQ, DARCOM	4,253
DARCOM, Personnel Support Agency	23,136
Armament Research and Development Command	71,264
Armament Materiel Readiness Command	11,444
Missile Research and Development Command	3,946
Signals Warfare Laboratory	1,994
Ballistics Research Laboratory	20
Communications and Electronics Materiel Readiness Command	92
Communications Research and Development Command	86
Combat Surveillance and Target Acquisition Laboratory	274
Electronics Technology and Devices Laboratory	179
Electronic Warfare Laboratory	919
Night Vision Laboratory	607
Foreign Science and Technology Center	189
Mobility Equipment Research and Development Command	111
Tank Automotive Research and Development Command	249
Dugway Proving Grounds	20
Other DARCOM	(405)
Project Managers (PM's)	
TRADE	8
ATACS	160
ATSS	30
BETA	250
CAWS	2,031
DIVAD	520
GSRS	3,670
Hawk	445
Lance	39
NUC	833
Patriot	8,179

DARCOM Source (cont'd)	$K
Roland	60
SA	1,146
SINCGARS	337
Other PM's	(12)
Subtotal	*$167,861*

Other Army	$K
Training and Doctrine Command	3,246
Operational Testing and Evaluation Agency	116
Corps of Engineers	3
Army Communications Command	833
HQ, DA	831
Other	2
Subtotal	*$5,031*

Non-Army	$K
Air Force	2,415
Navy	1,617
Defense Nuclear Agency	3,044
Defense Communications Agency	650
Department of Energy	214
Department of Interior	10
Marine Corps	14
Federal Bureau of Investigation	30
Library of Congress	51
Lockheed	81
National Security Agency	94
Nuclear Regulatory Commission	94
National Bureau of Standards	13
National Aeronautics and Space Administration	34
Miscellaneous	6
Subtotal	*8,367*

Grand total **$181,259**

Table 4. Outside/Inside Obligations as of 30 September 1979

Effort	Total $K[a]	Industry and academia—contract obligations		Other DARCOM labs[a]—contract obligations		Other Government agencies—contract obligations		Estimated cost to administer[b]	
		$K	% of total	$K	% of total	$K	% of total	$K	% of total
RDTE[c] funds									
6.1	4,578	246	5	500	11	278	6	2	<1
6.2	12,545	1,489	12	2,492	20	439	3	10	<1
6.3a	8,288	1,167	14	1,951	24	1,459	19	5	<1
6.3b	14,781	434	<3	248	<2	8,507	58	4	<1
6.4	23,236	6,183	27	154	<1	6,625	29	20	<1
6.5	6,847	2,968	43	315	<5	1,601	23	1	<1
6.7	1,891	94	5	—	—	—	—	1	<1
RDTE total	*72,166*	*12,581*	*17*	*5,660*	*1*	*18,909*	*26*	*43*	*<1*
Procurement funds									
DARCOM	64,788	53,895	83	118	<1	38	<1	1,944	3
Other Army	—	—	—	—	—	—	—	—	—
Non-Army	67	—	—	—	—	—	—	—	—
PAA[d] total	*64,855*	*53,895*	*83*	*118*	*<1*	*38*	*<1*	*1,944*	*3*
OMA[e] funds									
DARCOM	2,176	1,349	62	—	—	—	—	—	—
Other Army	24,796	469	<1	49	<1	18	<1	—	—
Non-Army	587	10	2	—	—	—	—	—	—
OMA total	*27,559*	*1,828*	*1*	*49*	*<1*	*18*	*<1*	—	—
Grand total	**164,580**	**68,304**	**42**	**5,827**	**4**	**18,965**	**11**	**1,987**	**1**

[a] *Total obligations for each line: 6.1, 6.2, and so on.*
[b] *In-house costs for purely administrative duties, both technical and managerial.*
[c] *Research, development, engineering, and testing.*
[d] *Procurement appropriation, Army.*
[e] *Operations and maintenance, Army.*

Table 5. Total Expenditures AIF/NAIF (FY79)

Type of expenditure	AIF $K	AIF %	NAIF $K	NAIF %	Total ($K)
Salaries and wages	31,243	61	19,844	39	51,087
Supplies and materials	3,454	100	6	0	3,460
Contractual services	17,453	17	85,234	83	102,687
Capital equipment	1,531	63	896	37	2,427
Other costs	3,251	99	15	1	3,266
Total	56,932	—	105,995[a]	—	162,927

[a] *These figures include $19,766K of disbursements made by HDL for the DARCOM Centralized Career Intern Program.*

Table 6. Percentage Breakout of In-House (AIF) Cost

Type of expenditure	%
Salaries and wages	55
Supplies and materials	6
Contractual services	31
Capital equipment	3
Other costs	5
Total	100

Average man-year salary: $26,284
Average man-year cost: $48,576

Table 7. Use of Personnel

A. Profile of technical personnel

Personnel	Authorized	On board	Professionals (scientists and engineers) Doctors	Masters	Bachelors	Other	Avg age	Avg grade	Technicians No.	Avg age	Avg grade
Military	5	4	1	1	2	0	33.8	—	0	—	—
Civilian	615	615	56	113	212	11	43.8	12.5	223	44.6	10.7
Total	*620*	*619*	*57*	*114*	*214*	*11*	*43.7*	*12.5*	*223*	*44.6*	*10.7*

B. Distribution of man years of effort as of September 1979

Personnel breakdown	Man years according to source of funds: DARCOM RDTE[a]	DARCOM Proc[b]	DARCOM OMA[c]	Non-DARCOM RDTE	Non-DARCOM OMA
Classified Act total	719	231	43	22	5
Administrative	212	59	10	4	1
Professional (S&E)	292	81	14	4	1
Professional (Other)	75	50	13	11	2
Technicians	140	41	6	3	1
Support	0	0	0	0	0
Wage board total	152	—	—	—	—

[a]*Research, development, engineering, and testing.*
[b]*Reimbursable funding.*
[c]*Operations and maintenance, Army.*

chapter 2. mission summaries

fuzing

Exploratory Development

HDL conducts a broad program of applied research to develop and maintain the technology base in support of electronic fuzing. The major portion of this effort is funded by the Large Caliber Weapons Systems Laboratory, ARRADCOM, under project 1L662603AH18-14. The target sensing portion of the program is directed at understanding and exploiting all applicable physical phenomena (for example, radio/radar, optic, magnetic, electrostatic) for sensing/measuring fuze-target dynamics, as well as investigating modulation/demodulation techniques, signal processing, and target characteristics ("signatures"). Strong emphasis is placed on achieving invulnerability to electronic counter-countermeasures (ECCM). The program also includes the research and development of necessary subsystems and components such as reserve batteries, safety and arming mechanisms, and microwave components (including conformal antennas, rf power sources, and integrated circuits). Finally, the supporting technology effort addresses unique material needs such as encapsulants, sealants, and adhesives, laboratory and computer simulation techniques, and computer-aided design. The ultimate objective of this continuing R&D program is to develop the basic knowledge and prototype fuzing systems which will lead to the expeditious development of reliable fuzes to satisfy future Army needs in a timely and cost-effective manner.

Target Sensing.

Air-Defense Missile Fuze. The air-defense (AD) missile fuze program is directed towards the needs of short-range AD systems. The program addresses the anticipated requirements of 1987, which include the improvement of ECCM capabilities. In particular, the threat of dedicated fuze jammers is taken into account.

A critical item is the transmitter, which must have sufficient rf pulse output power. IMPATT oscillators have been used in the AD fuze at X-band frequency, and a microwave integrated circuit (MIC) configuration of such an oscillator has been ordered for investigation and incorporation into the breadboard. However, expectations that X-band IMPATT oscillators with 100 W or more of pulse power would become available have not been fulfilled, and there is little hope now that such oscillators will become available in the foreseeable future. The present state of the art of IMPATT power-oscillator development at X-band allows about 10 W of rf peak pulse power with 1 to 5 percent dc to rf conversion efficiency. This efficiency is quite low, which is in part due to the short pulse widths that are required for the application. As a consequence, other methods had to be found to approach the 1987 achievement goals.

One promising method appears to be the use of a very narrow antenna beam to discriminate against self-screening jammers (SSJ's). This scheme was investigated theoretically and then experimentally by field-test measurements at Blossom Point. There, the signatures of a target with an SSJ were obtained for various target positions. These returns showed that the narrow fuze antenna beam did indeed discriminate against the SSJ as expected. A very considerable burn-through improvement of 20

to 30 dB could be shown. The creation of a narrow antenna beam pattern requires a sufficiently high ratio of aperture to wavelength. Because of the restricted space available for the antenna, the frequency will have to be shifted from X-band to lower Ka-band. This shift to higher frequency may cause a problem because of increased rain returns; however, calculations show that the specifications will still be met.

Monopulse Fuze. The objective of the monopulse fuze effort is an effective AD missile fuze capable of high performance in the presence of electronic countermeasures (ECM). Application of the monopulse radar principle, combined with the use of appropriate signal-processing and decision circuitry, makes possible a fuze system which provides unique ECCM capabilities and accurate location of the target before the point of closest approach. Low-speed encounters between the basic monopulse fuze and a suspended A4D jet aircraft have been obtained in the field. Data from these low-speed encounters will be used as the input for computer simulations of high-speed encounters. Techniques are being investigated which will enable the monopulse fuze system design to be compatible with solid-state rf sources currently available. Future plans also include optimization of all fuze functions using the results of the high-speed encounter simulations and other analysis and experiments.

Air-Target Electrostatic Fuzing. Under most flight conditions, aircraft accumulate charge through triboelectric effects or combustion processes. In principle, an electrostatic fuze senses the charge field to cause detonation at the optimally lethal distance from the aircraft.

Past study in electrostatic fuzing at HDL has been performed in the laboratory. An indoor model range was built and used to record target signatures for selected encounters with a one-seventh scale fixed-wing aircraft. Probe responses to atmospheric electricity were estimated through laboratory simulation and interpolation of basic atmospheric charge and field data in the literature. Fuze performance against hypothetical ECM was analyzed with computer simulations.

Promising results from these past studies provoked increased interest and funding for FY79. This year, field firings were planned to verify the laboratory probe responses to full-scale targets, charged precipitation, and cloud fields. To achieve this, HDL has designed an electronics package containing probe, amplifier, and rf telemetry circuitry. This package has been tested in the air gun and shown to be capable of surviving the shock of gun firing. Currently, 14 packages are being constructed for firings that will take place at the beginning of FY80.

Anti-ARM Fuzing. A serious threat to Army battlefield radars and emitters is posed by anti-radiation missiles (ARM's). This program examines the fuzing role required when present AD missiles are used in the anti-ARM mission.

Four targets have been selected, to include different likely encounter situations. Radar target models have been developed for each of these selected targets. These radar models have been incorporated into an extensive program, LEGS (Lethality End Game Simulation), which simulates the terminal encounter geometry and models the way the fuze processor circuitry acts on the dynamic radar return signals. The firing of the fuze and the relative positions and aspects of the missile and target are found. A preliminary analysis will determine whether, with the present operational characteristics, the various fuzes will perform satisfactorily. This analysis will be followed (if necessary) by an analysis of feasible modifications which enhance fuzing performance in this role.

Coded-Phase Fuzing. The objectives of the coded-phase fuzing project are the understanding, evaluation, and design of phase-coded, continuous-wave ranging schemes which are less subject to jamming and Doppler ambiguities than current schemes. Computer analysis on several developmental coded-phase schemes has been performed to assess their ECCM performance and Doppler dependence. The sensitivity of these schemes to waveform distortion has been analyzed, and useful results have already been applied to a current fuze program. The analysis aided considerably in the design of the code generator and modulators, and

the bench test results agreed well with the predictions.

With the computer programs established, we now have an analytical tool for the analysis and synthesis of phase-coded systems which includes the effects of Doppler, polyphase codes, and code imperfections.

Ground Clutter Spectra at Very Low Altitude. AD missile fuzes engaging low-flying targets have the problem of distinguishing valid target signals from ground clutter. Clutter statistics and spectra undergo changes when observed from very low altitudes, and clutter models are needed to solve this problem.

To establish a data base, a probe has been mounted in a helicopter and clutter data have been collected from altitudes below 20 m. The altitude was maintained with a split-image rangefinder with two TV cameras on the rangefinder baseline. Open fields, pine forests, scrub pine, deciduous forests, and composite forests have been probed. Good quality data have been obtained and will be digitized for complete computer analysis.

Aerosol Discrimination for Optical Fuzing Systems. HDL is continuing research on the problems that now limit the application of optical sensing techniques to fuzing. Active optical fuzing sensors transmit a light pulse and sense the energy reflected by the target to detect proximity or measure range. Backscattered radiation from aerosols, which can be mistaken for a reflection from a target, is a serious problem. HDL is developing a data base of scattering properties of aerosols and is investigating various aerosol/target-discrimination techniques.

A nephelometer, designed and built at HDL, provides data to characterize the cloud environment by measuring extinction and backscatter coefficients. These measurements not only provide the needed independent variable for comparing backscattered intensities for various systems and aerosols, but also provide cloud maps showing the range and variation of the coefficients. A pulsed laser probe, also designed and built at HDL, measures the temporal and polarization characteristics of aerosol backscatter signals. The optical pulses are about 5 ns wide and may be linearly polarized. Two receiver channels collect data on the amplitude, shape, and polarization state of the backscattered pulse. The major present interest is to discover how the pulse shapes of returns from legitimate targets differ from those of aerosols, and how to exploit these differences for discrimination.

Aerosol backscatter data were acquired this year in natural clouds, fog, smokes, and dust. The cloud data were obtained in two series of tests in which the nephelometer, the laser probe, and the data-acquisition system were mounted in a helicopter which flew through the clouds. Data were obtained in early fall cumulus clouds using TECOM aircraft from Aberdeen Proving Ground, MD, in October 1978; during May and June 1979, spring cumulus and stratus cloud types were measured with the aid of the ERADCOM flight facility at Ft. Belvoir, VA. Data must be obtained in different clouds because statistics are needed on densities, scattering properties, and density gradients. The gradients were measured to higher resolution than previously by the use of a modified configuration of the laser probe in some of the flights. The steepness of the gradients, especially on exit from clouds, is very important to aerosol target discrimination. Backscatter and extinction coefficient data in fog, smoke, and dust were obtained at Eglin AFB, FL, during Smoke Week II, run by DARCOM's Project Manager Smoke/Obscurants. HDL's participation in this test is described under *Penetration of Obscurants* (p 105).

In air-target fuzing, wide-angle coverage (usually 360 degrees) is often a requirement. Aerosol discrimination methods are especially critical with wide-angle systems, because aerosols can occupy a large part of the beam, while legitimate targets usually intercept only a relatively small part. An investigation of discrimination methods for optical fuzes having fan-beam influence patterns was begun last year and continued through the current year, producing a number of significant achievements. The investigation centered around the use of pulse-shape discrimination and range-response tai-

loring to achieve aerosol immunity, and also considered various fan angles ranging over a full quadrant.

A mathematical formulation was devised and computerized last year to calculate, for the fan-beam geometry, the time variation of return signals from arbitrarily shaped and oriented targets with specifiable reflectivity characteristics (in terms of the angular distribution of reflected power).[1] A similar formulation was computerized this year for calculating aerosol return signals resulting from an arbitrary encounter with a cloud having a uniform density interior and specifiable linear edge buildups. Using the analytical capability, a systematic study was conducted to determine target and aerosol signal amplitudes and pulse shapes for a representative sample of realistic encounter situations. Figures 1 and 2 illustrate some of the results.

Figure 1 shows the variation of the amplitude and pulse width of the aerosol return signal for two systems with different range-response characteristics, as the systems pass through a cloud with 2-m edge buildups and a uniform interior extinction coefficient level of 0.1 m^{-1}. Each system has a 90-degree fan-beam influence pattern and a 5-ns rectangular transmitter pulse. The different range-response functions are shown in figure 2. The signal amplitudes are normalized to unity when they equal that returned by a 1-m section of target, centrally located in the fan, having a diffuse reflectivity $\rho = 0.1$, and oriented perpendicular to the fan axis at a range of 5 m from the transceiver.

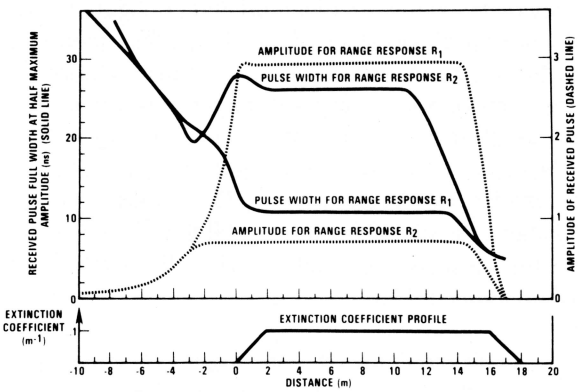


Figure 1. Variation of amplitude and pulse width of aerosol return signal for two 90-degree, 5-ns fan-beam systems as they pass through cloud with 2-m edge buildups and uniform interior extinction coefficient level of 0.1 m^{-1}.

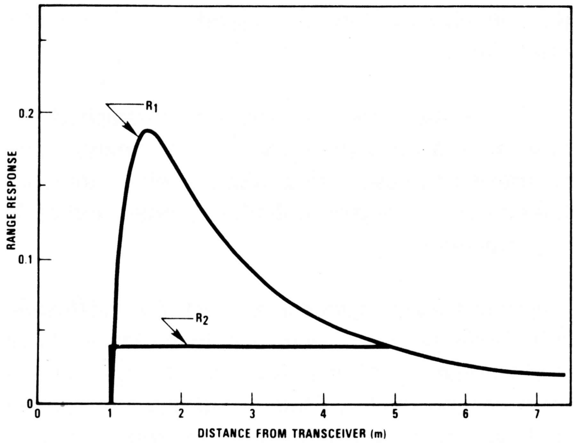


Figure 2. Range-response functions of the two systems of figure 1.

The figures illustrate the generally large degree of pulse stretching usually present in the aerosol returns and show the relatively strong dependence of the signal levels on the range-response characteristic. By contrast, the target return signals show very little pulse stretching at the half-maximum points for the vast majority of cases.[1] The figures also show that exit from the cloud can be a special problem, because the pulse width narrows before the amplitude decreases. How severe the problem is depends on the steepness of gradients in real clouds; the solution may require further processing logic.

The foregoing study showed that aerosol discrimination using pulse-shape recognition and range-response tailoring is promising. A preliminary evaluation of a discrimination scheme using both these techniques gave encouraging results for a 90-degree fan-beam system with a 5-m function

[1] *G. Stolovy, Fan Beam Optical Fuze Pulse Return Modeling, Proc. 19th Annual Student Technical Symposium, Harry Diamond Laboratories (1978).*

range.[2] This work will be continued, with some additional emphasis on the implementation of desired range-response characteristics and pulse-width sensing circuitry. Several technical reports discussing the work in detail are in preparation.

Active Optical Proximity Fuze for Small-Caliber Gun Munitions. HDL continued the investigation of a small active optical fuze for use with 35-mm guns in the AD role. An optical fuze is attractive for this application because of its immunity to countermeasures.

The fuze uses pencil transmitting and receiving beams focused at the design sensing distance. Because of the focusing, and because the transmitting and receiving lenses are separated, there is a very rapid fall-off of sensitivity beyond this distance. A multiple heterojunction GaAs laser provides 0.5-W peak optical output at a 1-percent duty cycle. The 100-kHz repetition rate and shell spin combine to sweep the pencil beam around the shell and sense targets at any azimuth.

A model of an optical system that fits into the ogive of a 35-mm shell and provides the required range-response curve, constructed for HDL by a contractor, is shown in figure 3. This model includes breadboard versions of the transmitter and receiver electronics, which are not yet miniaturized and integrated to fit into the shell. HDL has evaluated this model, and found that the expected range-response function was achieved. However, problems in achieving and maintaining the alignment of the optics, as well as with the performance and lifetime of the laser source, were discovered; these problems will be addressed in FY80.

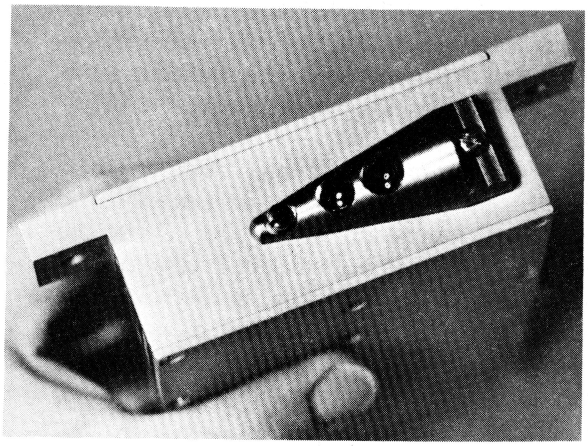


Figure 3. Optical system model for shell fuze.

To test the performance of the sensor in aerosols, instrumented flight tests were made through clouds, with the shell sensor mounted on a helicopter. No backscatter returns exceeding the firing threshold occurred—in fact, no backscatter returns above the noise level were seen. Unfortunately, the system sensitivity at the time of these tests was degraded because of the problems mentioned earlier, so the results are not conclusive. The tests will be repeated in FY80, after the sensor modifications are completed.

Optical Fuzing Transmitters and Receivers. HDL's investigations of very-short-pulse technology for application to optical fuzing systems and the aerosol optical backscatter probe have previously produced GaAs laser transmitters with subnanosecond rise times, and fall times of less than 2 ns. This year, new circuits have been designed using two avalanche transistors in series to discharge the low-impedance pulse-forming line through the laser, and high-efficiency, low-threshold-current GaAs lasers are now available; these new developments have enabled HDL researchers to achieve peak pulse-power outputs of over 50 W with similar rise and fall characteristics. A transmitter of this type has been incorporated into the short-pulse aerosol probe.

Although the 50-W power output is a large increase over that previously attained, it is lower than anticipated, indicating that the peak pulse current generated is lower than that obtained with the previous lasers. Since the only change is the lasers, we must assume that the new lasers have a higher forward resistance. The manufacturer has agreed to select lasers for efficient operation at even lower currents. Because the more efficient lasers

[2]*G. Stolovy, Computer Study of a Target/Cloud Discrimination Scheme for a Fan-Beam Optical Fuze, Proc. 20th Annual Student Technical Symposium, Harry Diamond Laboratories (1979).*

may have an even higher forward resistance, the achievement of even those low currents may be prevented. Therefore, a parallel effort is proceeding to further reduce the line impedance, in order to increase the pulse current.

The integrated receivers (avalanche photodiodes and transimpedance amplifiers) developed on a small HDL-sponsored contract were evaluated and found to have good noise properties and bandwidths of about 150 MHz, adequate for optical fuzing with pulse-shape discrimination. These receivers may also be used in the aerosol probe. Detectors and integrated photoreceivers manufactured in West Germany were evaluated in a program financed by the Foreign Science and Technology Center; these were found to have extremely fast rise times but severe tail-off on the trailing edge of the pulse. The latter characteristic renders them unusable in systems in which the fall time is used for target recognition.

Ground-Target Fuzing. Theoretical, laboratory, and computer evaluations of existing and proposed ranging systems for proximity fuzing applications are being conducted. Theoretical analysis has been done of the response of systems to various targets and terrain in the presence of ECM. Mathematical models for the prediction of the effects of ECM on the systems' performance are being developed. Results are verified by laboratory measurements on the system.

A tactical ECM field environment has been simulated by computer and used in evaluating three different fuzing systems. The input to the program is the laboratory measurement of the susceptibility of a particular system to ECM, as well as the pertinent operating parameters of the system. The output of the program is a prediction of the probable vulnerability of the system to the field environment selected for the simulation. The program takes into account the coupling of the fuze to multiple jammers and their reflections, the roll rate and velocity of the vehicle, antenna patterns, terrain coupling, and the dynamic response of the system.

This program has been applied to the analysis of the performance of two high-altitude fuzes, one operating at 200 ft (62 m) and the other at 2000 ft (620 m). These systems are of the type described under *FM Systems.*

FM Systems. Several new frequency-modulated (FM) system concepts have been demonstrated. These concepts use frequency modulation together with two correlations and digital signal generation to improve range responses. Various different range responses can be obtained by a change of amplifier bandwidths and the programming of a read-only memory (ROM). Laboratory tests show that these systems, used against ground targets, can produce heights of burst from near 0 to over 2000 ft (620 m). An air-target implementation has been demonstrated for a 6-m miss distance. The maximum miss distance has not been determined, but will of course depend on the particular target and the allowed fuze size and cost.

ECCM Air Encounter Simulation. Computer simulations of radar fuze air-target encounters are being developed to analyze system performance in both benign and ECM environments. The proposed simulation programs are used to obtain fuzing positions for various systems, and are designed so that ECM signals can be added, allowing their effects on fuzing to be studied. The fuzing position data can be combined with warhead effects and target vulnerability data to assess kill probability. A comparison of different fuze systems and the effects of modifications to system parameters can be studied in terms of overall effectiveness against jamming.

The fuze air-target encounter has proved to be very difficult to analyze or simulate, since the fuze passes very close to the target. The keys to the proposed simulations are efficient access to large amounts of experimental data and an extensive graphics capability. The simulation programs accept a wide variety of velocity-scaled, experimental target returns obtained from the Patriot, Roland, DIVADS, and Chaparral programs, and extensive interactive graphics programs have been written to facilitate interpretation of the large amounts of available data. The computer models have been developed directly from the data, and are also being verified from the data. Previous models have not had the benefit of this close association with

experimental data, and have therefore not been adequately validated.

Within this framework, a joint program with the UK for The Technical Cooperation Program (TTCP) Panel W3 has been undertaken. The objective of this program is to compare methodologies for computer modeling of fuzes. For this purpose the UK is providing MIG-21 signatures from one of their experimental radar fuzes, and the US is providing a model for a sample fuze processing logic system. The UK signature data will be very useful for analysis and validation of models, since the data were taken at a frequency and antenna beamwidth for which the US has no experimental data.

Chaff Modeling. Effective fuzing performance against an air target engaged while passing through a corridor of chaff is dependent on the fuze's ability to distinguish the target from the chaff. The fuze must discriminate the reflectivity characteristics of the target from those of chaff in a way that avoids fuze prefunction on the chaff return signal while still allowing the fuze to function at the proper time during target intercept. The design of proximity fuzes with such attributes requires models for chaff that are sufficiently detailed to properly characterize the signals returned from the chaff particles, yet are simple enough so that the models are mathematically tractable when used in simulations of encounters encompassing long spans of trajectories passing through chaff corridors.

For these purposes, chaff has been modeled by assigning randomly selected coordinates to each of the chaff dipoles which collectively constitute the chaff cloud. Since the reflectivity of each dipole is dependent on its orientation with respect to the incident field, random angles are also used to describe the dipole orientations. Once positions and angles are selected they may be assumed to remain static during the brief period of fuze encounter. In this way computer simulations have been used to generate ensembles of Doppler voltage waveforms as seen by a coherent fuze signal processor moving along selected trajectories through the chaff cloud. The resultant chaff signatures include both (1) the phase modulation entailed as the relative positions of the individual dipoles shift and (2) the amplitude modulation induced by the dipoles' traversal of the fuze antenna beam. These simulated chaff signals can be used to evaluate computer representations of various fuze signal processors.

Other characteristic features of chaff return signals have been elicited by subjecting these simulated Doppler voltage waveforms to Fourier analysis, to autocorrelation techniques, and (for pulsed fuzing signals) to the determination of the extent of pulse stretching of the return signals. Comparisons of such features with corresponding features of target-reflected signals allow the selection of the most important distinguishing characteristics that may be used to develop new fuze concepts.

Signal Processing. It is frequently possible to discriminate between signals reflected from targets and those due to a chaff or terrain background on the basis of the spreading of the Doppler frequency spectrum. Signal processors that can distinguish between varying degrees of spectral spreading may be used to advantage in detecting targets in high clutter backgrounds. One such processor employs digital correlation techniques in such a way as to reject signals of a preselected bandwidth while detecting narrower band signals.

A simplified diagram of the processor is given in figure 4. The input to the processor is the Doppler signal reflected from the target and/or clutter, which is initially shifted by 90 degrees to develop a quadrature replica of the signal. Both shifted and unshifted versions are limited and multiplied digi-

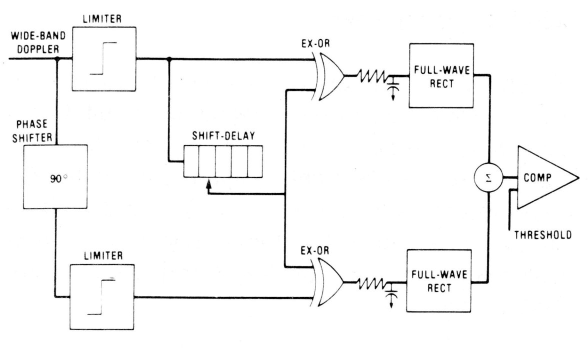


Figure 4. One-bit digital processor.

tally by a time-delayed version of the unshifted signal. Following integration, the two multiplied signals are added together and the result is compared with a preset threshold.

The resultant output of the summing device is a normalized version of the correlation function of the envelope of the narrow-band Doppler input which has been evaluated at the time delay. Thus, a wider bandwidth input will result in a lower summed output for any delay than will a narrow bandwidth target signature. The time delay may be adjusted to provide optimal clutter rejection while preserving a high probability of target detection.

Three other new ECCM signal-processing concepts have been demonstrated, all of which are applicable to constant false-alarm rate (CFAR) systems. One concept uses multiple pulse widths and a new rapid-rise pulse oscillator to improve ECCM performance. The other two concepts are applicable to both pulse and FM systems. One of these uses a new method of generating a comb filter to eliminate modulation byproducts and looks at jammer-produced interference.

Microwave Components.

Microwave Solid-State Pulse-Power Sources. Two different types of avalanche-diode pulse-power sources using combing schemes were developed. Emphasis was placed on sources employing GaAs read-type IMPATT diodes at X-band frequencies. These sources will find potential application in AD fuzing systems. The main objective is stable operation with a clean power-frequency spectrum (good noise properties).

Version 1. A dual-diode oscillator (illustrated in fig. 5) using microwave integrated circuit (MIC) technology, demonstrated "self-locking" between the two oscillator branches. First results exhibited a pulse-power output of about 5 W at 8.8 GHz in narrow-pulse (~80 ns) and low duty factor (2 percent) operation. The waveforms and spectrum are shown in figure 6.

Version 2. In pursuing the generation of higher power, a four-cavity oscillator combination with a common output for power extraction has been developed. The opened device is illustrated in figure 7, which shows the cavity arrangement with the diodes in place. Coupling to the common capaci-

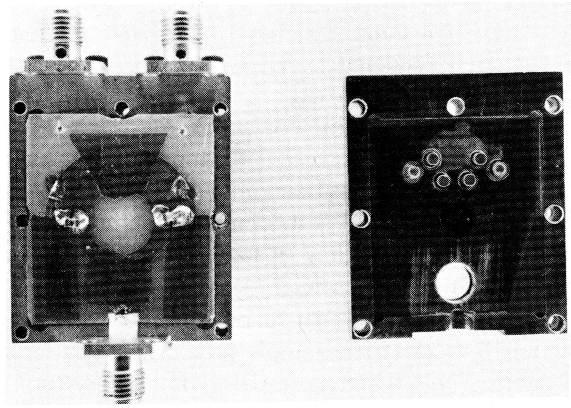


Figure 5. Dual-diode oscillator.

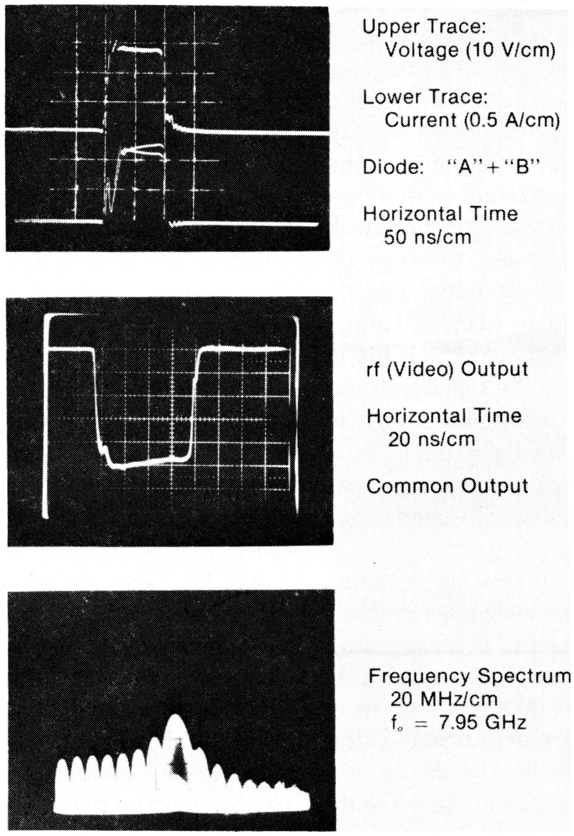


Figure 6. Waveforms and spectrum of dual-diode oscillator.

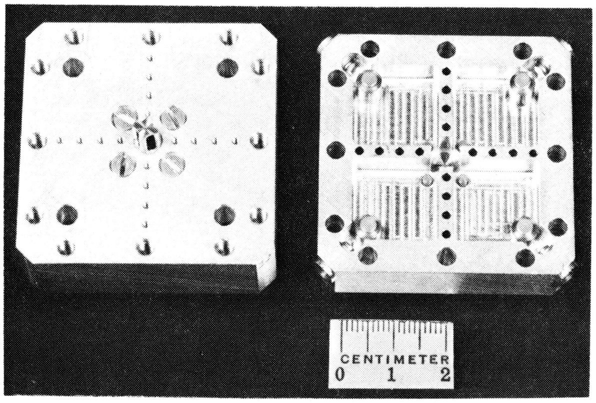


Figure 7. Four-oscillator combination, opened, with diodes in place.

tive output probe was achieved by means of a dielectric resonator, resonating at the same frequency as the cavities, which is magnetically and symmetrically coupled to the individual cavities. At the same time, the dielectric resonator stabilizes the frequencies of the four oscillators. Circuit measurements are shown in figure 8. In cw operation at a low power level, the self-locking feature of the four-diode oscillator has been demonstrated (see fig. 9).

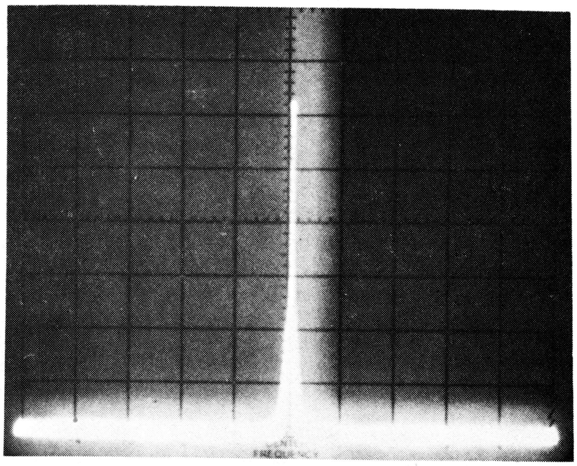
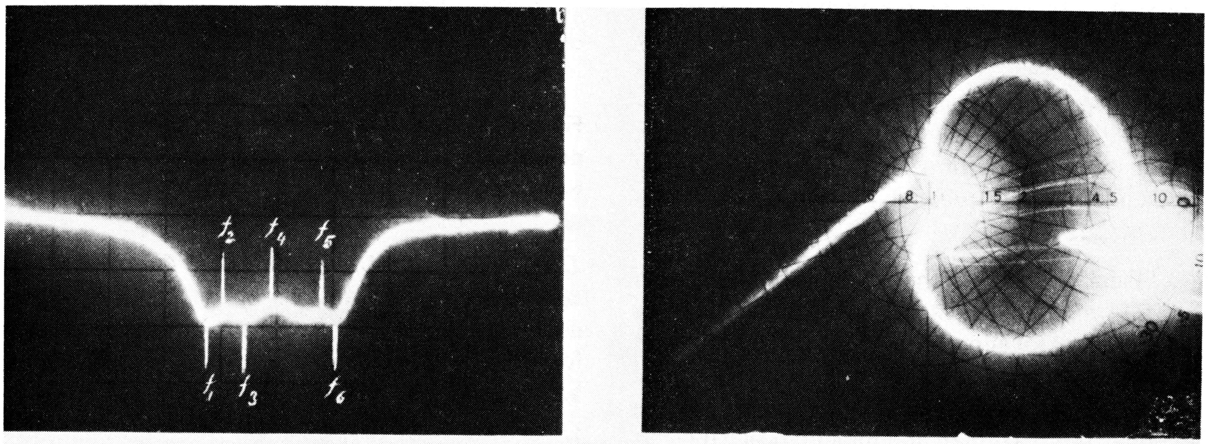


Figure 9. Four-oscillator cw spectrum—20 MHz/div.

Microwave Acoustic Delay Lines. Delay lines with up to a 250-ns delay have been produced using a mosaic thin-film Zn0 transducer and a series inductor matching element deposited on the end of the delay medium. These devices, which were developed at HDL and fabricated under contract, are designed to be hermetically sealed in a new 1/4-in. square stud-mounted microwave package



4-Diode Combiner, "Cold Tuned" for Bandwidth

f_1 = 10.69 GHz	V_B = 61 V
f_2 = 10.82 GHz	I_B = 0.83 mA
f_4 = 10.87 GHz	All Diodes
f_5 = 10.93 GHz	Amplitude: 10 dB/cm
f_6 = 10.95 GHz	Phase: 45°/cm

Figure 8. Circuit measurements for four-oscillator combination.

currently under development. The new package is 50 percent smaller than previous designs, which required a matching network at both input and output. The new stud-mounted design (fig. 10) allows the delay line to be mounted in the gun-rugged orientation and eliminates the need for mounting brackets and supports. It is estimated that this new package will reduce weight by more than 80 percent.

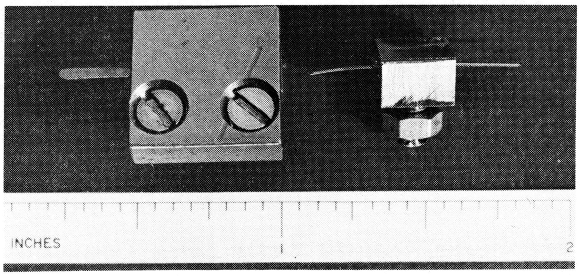


Figure 10. New stud-mounted package, compared to old package and mount.

Polarization-Diversity Microstrip Antenna. A new method for obtaining any desired polarization from a microstrip antenna has been developed. The method consists of placing one or more inductive posts at appropriate points within the antenna. Figure 11 shows a typical polarization-diversity antenna. The antenna can be fabricated through standard printed-circuit plating and etching techniques. It is very rugged, and, since it is very thin, it can be mounted conformally on a surface with very little effect on the structural and aerodynamic features of the surface.

Placing posts at the positions indicated in figure 11 results in the various polarizations. Placing posts at other locations yields elliptical polarization of any desired axial ratio. Figure 12 shows a typical radiation pattern taken with a rotating linear receive antenna. The maximum and minimum signal levels are almost equal near 0 degrees, indicating that the antenna has almost perfect circular polarization.

The use of rf switching diodes as inductive posts electronically changes the sense of polarization. This kind of polarization diversity, which is obtained from a conformal antenna, could be extremely useful in discriminating between desirable and unwanted signals.

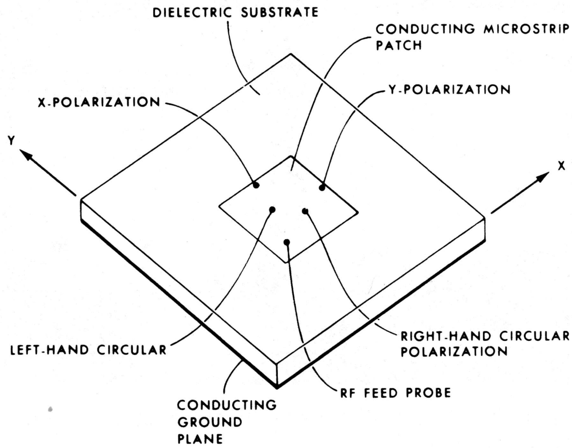


Figure 11. Typical polarization-diversity microstrip antenna.

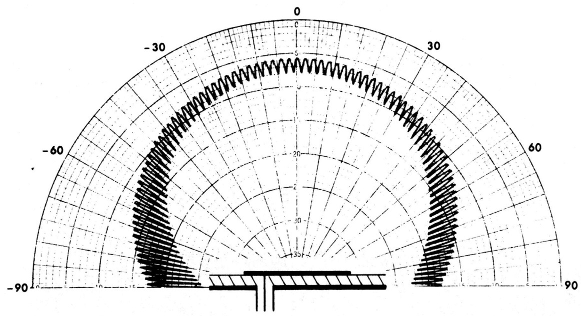


Figure 12. Radiation pattern of right-hand circular polarization configuration of polarization-diversity microstrip antenna.

Dual-Frequency Dielectric-Filled Edge-Slot Antennas. Series-fed versions of the dielectric-filled edge-slot antenna have been investigated and found to be useful as radiators in a multifrequency antenna. A basic, dual-frequency antenna, depicted in figure 13, consists of two discs of dielectric substrate sandwiched between three thin layers of copper. The inductive posts pass through one layer of substrate and connect the copperplated surfaces. The structure of the edge-slot antenna is ideally suited to mounting between sections of a cylindrical or conical body. The plated-through holes that form the inductive posts permit mounting bolts or cables to pass through the antenna without affecting its performance.

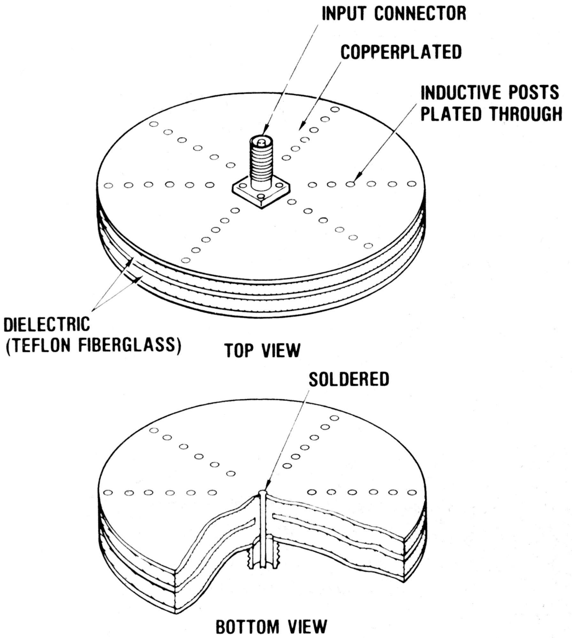


Figure 13. Dual-frequency, stacked, dielectric-filled, edge-slot antennas.

The operating frequency of the antenna is controlled by the number and locations of the posts. Using a different number of posts in the two discs results in two distinct operating frequencies. Figure 14 shows the voltage standing wave ratios (VSWR) of four dual-frequency antennas. In each case, one of the discs had five posts and operated at 2700 MHz. The operating frequency of the other disc varied as the number of posts was changed. Since the operating frequencies of the two discs may be independently selected within a 6-to-1 frequency range, this antenna has great potential for use in rocket and projectile systems that require conformal radiators with a dual-frequency operating capability.

Electronic Circuit Design.

Integrated Electronics for Low-Cost Fuzing. Work has continued on the effort to integrate on two chips the major electronic functions of a low-cost proximity fuze. The pulsed optical system requires an integrated, current-source, modulator chip to drive a light-emitting diode (LED), as well as

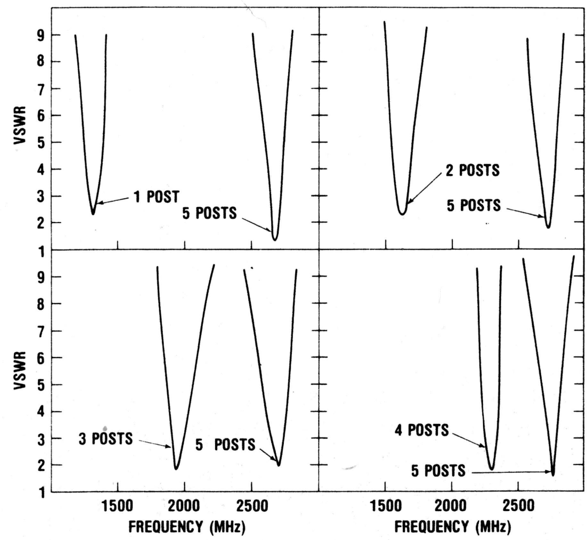


Figure 14. VSWR characteristics of four dual-frequency, stacked, dielectric-filled, edge-slot antennas (six elements, 76-mm diameter).

an integrated receiver chip with a high-gain amplifier, complex current-logic decision circuit, and firing network.

Initial modulator chips exhibited a proper circuit function, but at a supply voltage lower than required. Corrected masks were generated for use with the compatible diffusion process designed for simultaneous fabrication of both analog and digital circuits. The modified chip as shown in figure 15 fulfilled all the desired dc characteristics. With the specified load, the dynamic properties of the various circuit functions were at the edge of the desired operating specifications. Certain active elements

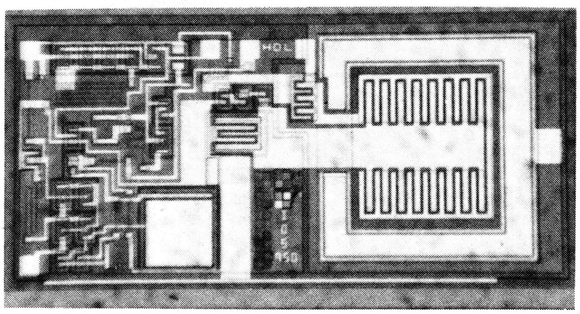


Figure 15. Transmitter modulator and driver.

required modifications, such as (1) larger geometries for the diode regulator and oscillator transistors and (2) reduction in collector resistance of the oscillator transistors; these modifications were needed for higher regulator current and shorter oscillator pulse duration. Design changes to correct these discrepancies are in progress. Experiments verified that the current drive of the LED is more than sufficient to meet operating specifications when a small diode is added in parallel with the regulator diode on the chip.

The initial working masks for the receiver chip were completed, and wafers were fabricated with the compatible process. The receiver chip is shown in figure 16 with the complex current-logic decision circuit occupying half the chip; the other half is the analog portion, consisting of two high-gain amplifiers, a voltage regulator, and a high-current firing network. Data from the initial run of wafers showed good dc characteristics at several stages of the amplifiers and at the Schmitt trigger, which precedes the decision circuit. The bias voltage for the optical detector is less than desired because of high-value pinch resistors; this low bias voltage can be corrected by adjustment of the emitter diffusion length. No conclusions can be drawn as to the chip's dynamic performance until measurements are made on packaged devices.

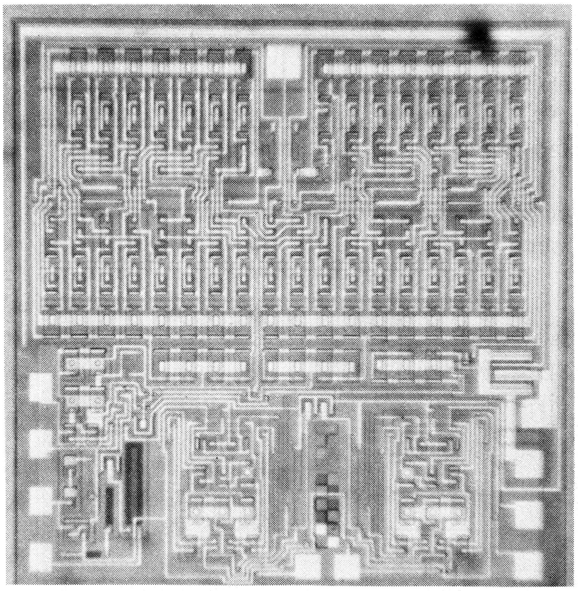


Figure 16. Receiver, decision circuit, and firing network.

Previous work done on the LED driver has been extended to an integrated pulse driver for a laser source. The driver must pass high currents, deliver sharp rise times, and maintain a pulse of short duration. An integrated transistor, shown in figure 17, was fabricated with alignment tolerances less than 1 μm and with the compatible process. This transistor is more than adequate for use in a Darlington configuration to drive an injection laser in an integrated laser modulator circuit.

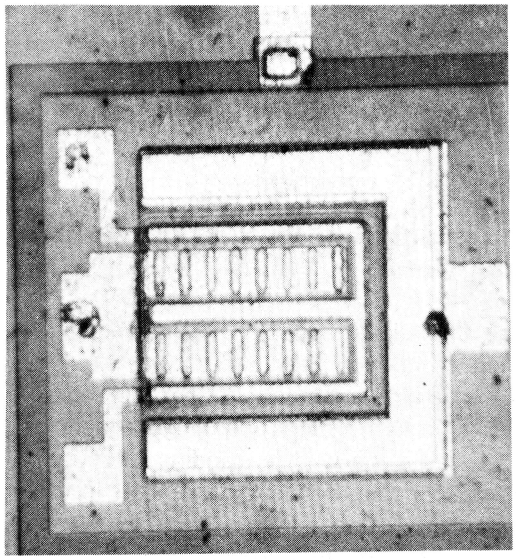


Figure 17. Integrated laser driver transistor.

Materials.

Support to Development Programs. Strong support in the area of organic materials was provided to the M735, XM749, M817, M734, XM587/M724, XM818, Improved Hawk, XM445, Sea Gnat, inductive-influence fuze, AN/PRC-77 radio, and expendable jammer programs. Services included testing, evaluation, selection, and recommendation of specific materials for hardware under development. The materials are being used for potting and encapsulation of electronics and as coatings and adhesives. Fuze programs in the procurement stage continued to benefit from increased

on-site monitoring of contractors' material processing and from close review of engineering change proposals.

A complete review of the M735 technical data package was made, and changes to material callouts, properties, and processing were recommended. With the end of the two-year sample aging period, the multi-agency materials compatibility experiment for the M735 fuze and M753 projectile neared completion. On the basis of interim results, the value of the experiment has been established, and initial planning has begun for a similar effort on the materials in the XM785 projectile and our XM749 fuze.

A major materials problem this year involved the solderability of eyelets in M732 timers. Laboratory detective work and plant inspections found that an organic contaminant on some eyelets originated in the contractor's solvent degreaser. Metallic contaminants that could reduce solderability were also discovered on eyelets in widely varying amounts. Their presence was traced to the eyelet fabrication process, and recommendations for added quality control were made.

Encapsulating Materials. A MACI (Military Application of Commercial Items) study for the evaluation and selection of encapsulating plastic for ordnance electronic assemblies was awarded to one of the five responders to a Request for Proposals put out by HDL. The state of the art in electronics encapsulation was reviewed. Approximately 50 resin formulators/suppliers suggested materials that could substantially reduce processing and cure times to about 1 to 5 percent of those needed for most encapsulants now in use. This development could produce substantial time, energy, and cost savings. This list was reduced to 21 for more detailed study of physical and chemical properties through laboratory testing. These tests have identified 10 products that will be used in trial encapsulations of hybrid and discrete component circuitry.

Electrochemical Power Supplies.

Lithium/Inorganic Electrolyte Reserve Power Supplies. Lithium batteries are particularly appealing because they provide unusually high energy densities and store well for long periods of time with little parasitic dissipation of stored energy. This makes them especially useful in the active state to meet medium-term military storage, although a reserve mode of operation is still required to meet long-term storage needs.

The storage characteristics are being investigated of single-cell lithium/thionyl chloride-lithium aluminum chloride/carbon batteries in a reserve configuration. Results of discharge tests after high-temperature storage for periods up to one year have shown no significant degradation in activation characteristics, provided that the hermetic seals at the cell terminals have been maintained.

Active Lithium Cell Evaluation. Active lithium/sulfur-dioxide and lithium/thionyl-chloride cells from three commercial sources have been evaluated in terms of their power and energy density capabilities and their storage characteristics. None of the cells have been able to meet the 160°F storage requirements; some fail in as little as one month.

Cells designed for high rate discharge have been shown to deliver greater than 5 W/in.^{3} for one hour and close to 10 W/in.^{3} for shorter periods. A method has been developed whereby the power and energy requirements for any given task can easily be evaluated in terms of present state-of-the-art capabilities.

Lead Dioxide Research. The lead/fluoboric-acid/lead-dioxide electrochemical system used extensively in the liquid reserve power supplies developed at HDL continues to be researched, with investigations of performance dependence on spin and very high power requirements.

A single-cell spin fixture has been optimized and has been shown to reproduce the cell lifetime versus spin rate characteristics found in complete multicell batteries. This device can now be used to evaluate proposed changes in battery electrochemistry without the need to construct complete batteries.

Discharge data taken up to extremely high current densities (about 10 A/in.^{2}) have shown that the internal impedance of lead/lead-dioxide cells is not constant, but rather is markedly dependent upon current density. The study of this phenomenon is being pursued to determine what factors in cell configuration influence this dependance and what the power limits of this system are.

Reserve Batteries for Small-Caliber Ordnance. Renewed interest in proximity fuzing for small-caliber ordnance has prompted support of the power-supply technology ultimately aimed at the design and prototype development of reserve batteries for use in 35- or 40-mm proximity fuzes.

Under consideration is a preliminary design that can deliver 125 mA at 15 to 20 V for 8 s; this design is contained in a package approximately 19 mm (0.750 in.) in diameter and 10 mm (0.4 in.) high. It would use a simple welded copper electrolyte container (ampule) and release electrolyte under setback without reliance on a complicated cutter mechanism.

A significant portion of this reserve battery work involves the development of test hardware that can evaluate such power supplies under rigorous conditions comparable to those encountered in the field (for example, a spin rate of 1200 rps). A contract effort is planned to provide for the design and assembly of a system in which the power supply can be subjected to actual gun conditions and be rapidly and nondestructively recovered for immediate evaluation of such design aspects as gun ruggedness, ampule operability, electrolyte distribution, and hydraulic integrity. The system will probably consist of a capped, smooth-bore tube several hundred feet long and fitted at one end with a rifled 35-mm Mann barrel. The power supply (or other fuze component) could be fired in an actual 35-mm projectile from the barrel into the tube of exact internal diameter. The capping causes the projectile to come to a gradual halt by the compression of air ahead of it. The test projectile could then be quickly recovered by venting the pressure via a release valve in the cap.

Electromechanical Power Supplies.

Miniature Hand-Cranked Generator. The miniature hand-cranked generator, the size of a pencil sharpener, contains a samarium cobalt rotor. Using the rare earth material as the permanent magnet makes possible a generator design with high power density. The alternator is being designed to generate 50 W when the machine is hand cranked at 60 rpm. The crank speed is increased 100 times by a harmonic drive, so that at an input of 60 rpm the alternator rotor speed is about 600 rpm. Because the amount of power required to operate a fuze setter is 5 W, approximately one turn of the crank handle is sufficient to set a fuze. Figure 18 shows a schematic drawing of the generator.

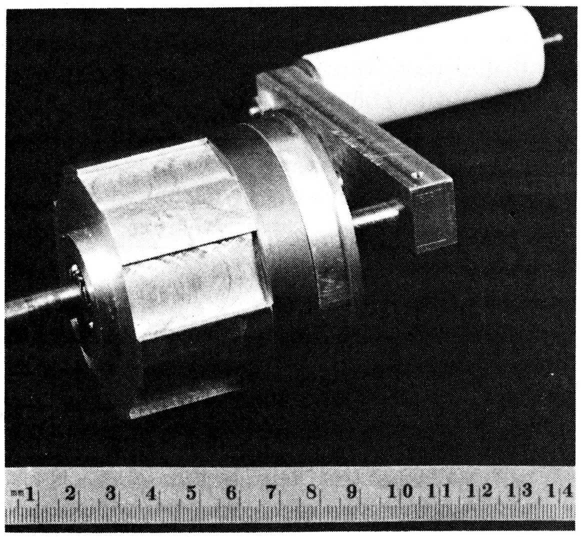


Figure 18. Miniature hand-cranked generator.

The use of a hand-cranked generator to power a fuze setter will eliminate the logistic and maintenance support needed when batteries are used. It will allow continuous availability of the setter in any combat situation or scenario. The generator is not adversely affected by temperature variations, and over an extended period of time, the generator has the potential of being less costly.

Turboalternator Power Supply for Artillery Fuzing. With the objective of potential cost savings, HDL researchers designed a turboalternator to pro-

vide power to an artillery fuze. As distinct from the turboalternator employed with the M734 mortar fuze, the artillery version must survive much higher setback forces and air velocity as well as withstand high levels of spin. Consequently, the stator and rotor are of smaller diameter and lighter, the alternator employs precision bearings, extra shaft support is provided, and the nylon in the turbine was replaced by aluminum.

Setback tests and spin tests have been conducted to insure that these forces would have no adverse effect on the performance of the alternator. In addition, several alternators were flown on Zuni rockets. The rockets achieved a burn-out velocity of 2700 ft/s (800 m/s)—comparable to artillery velocities—with the alternators operating satisfactorily throughout the flight.

Power Supply Cross References

For more information on power-supply work, see *Production Base Support,* in this section (p 47), for the following.

- MM&T Program on Turboalternators
- PS127 Liquid Reserve Battery for M587/M724 Fuze
- MTT Effort on Two-Channel Telemeter for Use in a 3-in. Spin Air Gun
- Modernization of Existing Mobilization-Base Electrode Plate Stock Facility

See also *Product Improvement* (p 49) for

- M734 Turboalternator.

In the section on *General Support* (p 112), see the following.

- Hard Structure Munition (HSM) Power Supply
- G-76( )/G dc Generator

S&A Concepts and Devices.

Electronic S&A Device. The electronic safety and arming (S&A) concept combines solid-state environment sensors, an electronic logic and firing circuit, and a special explosive barrier module (EBM) in an S&A device that can lower the cost and improve the safety and performance of future electronic fuzes. The EBM provides conventional barrier interruption using three propellant-driven interlocks in a simple, rugged, molded-plastic structure. In response to launch acceleration, in-flight aerodynamic forces, and arming delay signals, three identical electro-explosive initiators in a cover disc sequentially shear restraining pins on the interlocked sections to unlock and align a fourth initiator for munition functioning. Since only one of 24 possible initiation sequences results in an output, this scheme minimizes the possibility of unsafe conditions from accidental initiation.

Honeywell, Inc., was awarded a contract to develop a producible, low-cost design for the EBM and to demonstrate an electronic S&A system by building and testing 10 EBM S&A devices in an artillery fuze envelope. Their design for the EBM is shown in figure 19. The EBM is made of molded plastic and uses straight but flexible sliders moving in curved channels to provide detenting of the three sliders once they have been driven to the armed position. The electro-explosive initiators consist of only 4 mg of normal lead styphnate explosive ignited by 1000-erg thin-film metal bridge elements. These systems have been built and tested in the laboratory and have been found to function satisfactorily at all temperatures. However, an effort is continuing to perfect the design of the thin-film bridge deposited on a plastic substrate. A follow-on contract has been awarded with the objectives of

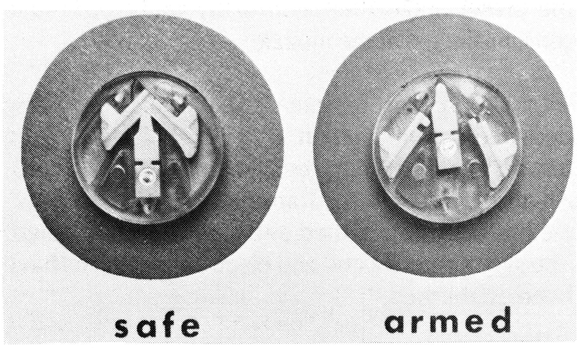


Figure 19. Design for explosive barrier module.

finalizing the electro-explosive bridge design, conducting development-type tests on 250 EBM's, designing a general-purpose electronic logic and firing circuit that can be built with a minimum number of components, and making a study of environmental sensors that can best be used with a low-cost electronic S&A device.

Other Exploratory Development.

Inductive Remote-Set System for Tank Application. The XM815 multipurpose high-explosive antitank (HEAT) tank round requires a remote-set system for setting a timer, for selecting the mode of function, and possibly for muzzle velocity correction. The inductive remote-set (IRS) system can provide these functions.

The tank fire-control system would output data to the setter unit (SU). When a projectile exits the muzzle, the projectile nose passes through the magnetic field of a synchronizing coil and then the magnetic field of the transmitting coil. A trigger signal is obtained from the synchronizing coil just as the projectile leaves the tube. After a delay, this signal triggers the SU to modulate the carrier with the data message. The magnetic field of the transmitting coil induces a signal into the receiver coil in the projectile fuze, which is detected and stored in the remote-set electronics in the fuze. When the projectile exits the muzzle, the synchronizing coil also provides a projectile velocity measurement which can be used to adjust the time data message for velocity variations. As the projectile continues toward the target, a fire pulse is generated either at the preset time-to-function or by the proper fuze sensor selected at the muzzle.

The SU and remote-set electronics are being designed in anticipation of a feasibility gun-firing test on the M106-mm recoilless rifle in early FY80. An arrangement of the transmitting coil at the muzzle has been established and structures fabricated. The synchronizing coil and electronics designs have been established.

Fuze for Special Hard Target Assault Weapon, LAW (SHAWL). MICOM is developing the SHAWL weapon, a shoulder-launched tandem warhead follow-through rocket, primarily intended for Military Operations in Urban Terrain (MOUT) applicatons. The SHAWL program is in exploratory development. HDL is developing the fuzing for the two SHAWL warheads.

Weapon and fuzing concepts were described in detail in the FY78 posture report. Program activity has been slowed pending resolution of warhead deficiencies. HDL activity during this report period was concerned with development of a miniature 10-ms stab delay primer which is required for the fuze in the follow-through warhead. An R&D contract for development of this primer has been placed, with hardware delivery scheduled in the fall of 1979. Field testing of the SHAWL weapon is expected to resume during the first quarter of FY80. If these tests are successful, MICOM will propose a 6.3 advanced development program.

Advanced Development

XM445 GSRS Fuze. The General Support Rocket System (GSRS) is a large-caliber multiple-rocket launcher system intended to support conventional artillery by providing heavy fire-power, especially in a battlefield-surge condition. To achieve high survivability, a "shoot and scoot" concept is used. Two six-round expendable launch pods that serve as both shipping containers and launch platforms are mounted on a self-propelled launcher loader (SPLL) which is a derivation of the Army's infantry fighting vehicle. The weapon system employs an automated fire-control and aiming system with a remotely set electronic time fuze. The time-fuze concept chosen by HDL uses the electronics from the M587/M724 fuze with a fluidic power supply and gearless S&A similar to those developed for the XM444 rocket fuze. This approach was chosen (1) to provide a low-risk development and (2) to take advantage of the larger production of the M724 electronic components to keep the production cost reasonably low.

More than 400 engineering models of the fuze (fig. 20) have been fabricated, and more than 42 of

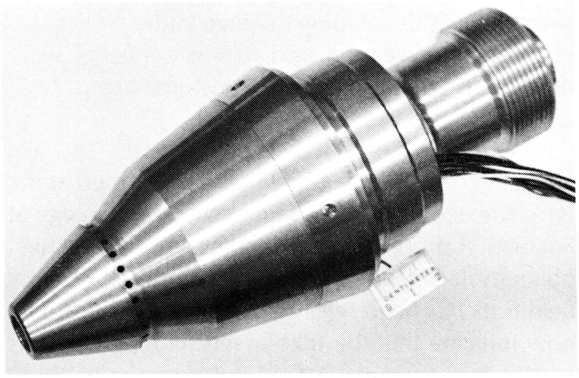


Figure 20. XM445 GSRS fuze.

these have been successfully flight tested on GSRS rockets. A fuze contract has been let to improve performance and reliability and to achieve low production costs through production design improvements.

The electronic timer is a slight modification of the one used in the M587E2/M724 artillery fuze which has been type classified.

The fuze setter will be part of a fire-control console inside the SPLL and will be the responsibility of the prime contractor. The fuze will interface with the setter through an umbilical cable.

Initial problems experienced with the fluidic generator power supply (momentary dropouts) have been resolved. The modified design has been successfully demonstrated in a number of flights.

The design for the interface between the fuze and fire-control console has received considerable attention since electrical interference on the fuze setting lines (including ground and in-flight electrostatic discharge) has been the apparent cause of several fuze failures.

The program has now completed engineering development tests (EDT-C) and is ready to start advanced development and verification tests (ADVT-C and ADVT-G) and operational tests (OT-I) in preparation for the Army Systems Acquisition Review Council (ASARC) III, which is scheduled in early 1980.

Surface Proximity Fuze. The purpose of the surface proximity fuze (SPF) program is to investigate fuzing concepts applicable to a high-velocity reentry vehicle. For maximum effectiveness and survivability, the fuze must function at less than 1 m away from either the ground or any obstacle in the vehicle's flight path. The combination of adverse environment (particularly plasma attenuation), high fuze sensitivity, and high range resolution requires the use of advanced fuzing concepts and technologies. This program is sponsored by the Air Force Space and Missile Systems Organization (SAMSO).

During the earlier part of the program, various optical and radar methods were investigated.[3] Although the optical approach has the advantages of high countermeasures immunity and a precisely defined influence pattern, its weather dependency and technological window problems render it inferior to the radar approach.

The study of the most suitable radar systems has continued[4] and resulted in the proposal of two alternative systems—one FM system and one high-repetition-rate pulse system. A third approach using binary phase modulation was also studied in depth but was found to be technologically not realizable for the SPF.

For the FM and pulse approaches, the system parameters, function blocks, and performance characteristics under benign and jamming conditions have been established; a particular effort was spent in analyzing fuze function with multiple, closely spaced targets. For both systems, a tentative circuit design has been carried out and was verified by breadboard models.

During 1979 the decision was made to concentrate effort on the pulse system, and procurement was initiated for prototype transmitters and receivers for this system from industry sources.

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[3] *Zoltan G. Sztankay and Wolfgang G. A. Wiebach, eds., Short Standoff Fuze Study: Final Report, Harry Diamond Laboratories, HDL-PR-77-1 (June 1977).*

[4] *Wolfgang G. A. Wiebach, Surface Proximity Fuze Study: Final Report, Harry Diamond Laboratories (to be published).*

Plans and documentation were also completed on an RFP for implementation of several complete fuze packages for later flight testing. Also included in this flight test effort will be experimental transmitter packages to measure the effects of plasma due to high-speed reentry.

Fuzing for Anti-Armor Weapons. Presently available fuze designs for anti-armor weapons have less than optimum standoff capability, restrict the munition's angle of impact, and cause it to perform poorly in trajectories that penetrate brush. The inductive-influence fuze overcomes these shortcomings by exploiting magnetic field effects.

The inductive fuze employs inductively coupled coils. A primary coil driven by alternating current is coupled to two series-connected sensing coils that are sized in turns, area, and spacing for zero output from the undisturbed field of the primary coil. When the field of the primary coil is disturbed by a conducting surface, the image field which is formed induces an output in the sensing coils.

A mathematical model of the target signal from a coil arrangement has been developed for optimizing the sensitivity and the influenced envelope. Preliminary studies are continuing for determining the performance of an inductive proximity-fuzed tank-fired HEAT round against a helicopter target.

A design has been completed for the fuze sensor to be incorporated into modified M106-mm, HEAT, M344A1 projectiles for use in feasibility demonstration firing tests. The firing of eight test rounds in the 106-mm recoilless rifle has demonstrated detonator initiation at approximately three cone diameters of standoff for target obliquities of 0 and 60 degrees.

Fuze for Shoulder-Launched Multipurpose Assault Weapon (SMAW). The Naval Surface Weapons Center at Dahlgren (NSWC-DL) is developing the shoulder-launched multipurpose assault weapon (SMAW) for Marine Corps use. The SMAW warhead is designed for use with the Viper rocket motor. In this program, now in advanced development, HDL is developing the fuze under NSWC-DL sponsorship. Weapon and fuzing concepts were described in detail in the FY78 posture report.

During FY79, HDL supplied fuzes for five advanced-development field tests performed at the New Mexico Institute of Mining and Technology at Socorro. A problem in hard-target sensitivity at high obliquity (60-degree) impact encountered in early field tests has been resolved. Limited field-test data now indicate that the fuze meets all major performance requirements. A field-test program of about 200 rounds is planned to more fully evaluate fuze performance during the next year.

High-Burst Proximity Fuzing. This development effort will provide the high-burst fuzing capability which is required for effective dispersion of submunitions for extended-range artillery rounds. It will use an altitude-above-ground sensor of the class successfully tested on the Parachute-Opening Proximity Sensor (POPS) system, which gave a height of burst (HOB) of 500 m. Several brassboard and configured prototypes will be fabricated and evaluated through laboratory simulations and environmental testing. An FM-cw sensing system was selected after analysis of various pulse and cw systems. This project has direct relevance to fuzing requirements for extended-range artillery submunition-carrying projectiles, and possible relevance to GSRS follow-on programs as well as guided projectiles.

To date basic system characteristics have been established, and although no specific delivery vehicle has been selected, packaging will be directed toward that suitable for smaller carriers. Brassboard sensors will be built and tested to show functionality. A design effort will be completed to package this circuit in an artillery-projectile fuze prototype configuration. This design will be compatible with existing hardware items such as S&A's, power supplies, and timers, where they are suitable. Extensive testing and evaluation will be completed through laboratory simulations and environmental testing. Critical design parameters will be elucidated and an assessment will be made show-

ing performance that would be expected for various types of terrain.

Divisional Air-Defense Gun System (DIVADS) Fuze Evaluation. A program to evaluate the two candidate proximity fuzes proposed by the competing commercial contractors for the DIVAD Gun System procurement is being conducted by HDL for PM-DIVAD. The effectiveness of proximity-fuzed small-caliber projectiles in producing target kills depends largely on the relative positions of fuzing points and vulnerable target areas. To evaluate proximity fuzing performance against various aircraft targets, large numbers of controlled projectile-target encounters must be effected (either in full scale or by simulation), target signatures must be recorded, and fuzing points must be determined.

DIVAD Probe Description. The most expeditious method of generating target signature data is to use scaled target models with the computer-controlled encounter geometry available at the Naval Weapons Center (NWC) Encounter Simulation Laboratory at Norco, CA. However, scaling the target necessitates the use of a fuze simulator at a scaled frequency to generate the data.

Two frequency-modulated radar ranging systems were developed—one to simulate each of the fuzes under study. A flat range response with a sharp range cutoff was required to represent the fuze rf performance and reject undesired target returns from the building walls. In addition, the sensitivity, signal-to-noise ratio (S/N), and dynamic range of these systems had to be superior to those found in the actual fuzes.

Data Recording and Fuze Point Determination. The target signatures as received at the scaled fuze probes are directly recorded in digital format at the NWC laboratory. In simulating the target encounters, both the projectile velocity and fuze wavelength have been scaled down. By modifying the time base and adjusting the amplitude scale of the recorded target signatures, analog versions of signatures for full-scale, full-velocity intercepts are reconstituted, and these signals are further processed by actual fuze hardware to determine fuzing performance in actual target engagements.

To simplify the determination of fuzing points for the large number of intercepts being evaluated, software representations of the candidate proximity fuze processors have been developed so that the digital signals may be applied directly and fuzing points computed. The validation of the software models of the fuze signal processors is based on comparisons of fuzing points based on these models with fuzing points determined by signal playback through the actual fuze hardware.

DIVAD Fuze Laboratory and ECM Testing. In addition to the above tests which evaluate fuze operation in a benign environment, various laboratory tests were performed to help characterize the fuze for computer modeling and to evaluate ECM performance. A variety of jamming signal types were introduced into the fuze oscillator and signal processor to determine fuze prefunction and dudding tendencies.

Engineering Development

XM818E1 Fuze for Patriot. The Patriot system (formerly SAM-D) is a mobile air-defense missile system being developed under the direction of the Project Manager's Office, DARCOM. In December 1970, after analysis of alternative proposals for fuzing the missile, the Project Manager's Office delegated to HDL the responsibility for the design, development, testing, and tasks related to logistical support of the fuze.

Early efforts resulted in a radar fuze design which significantly enhanced fuze performance in severe countermeasure environments. Electrical and mechanical design started at the same time as negotiations of the technical interfaces with the Project Office, the systems contractor, and the missile contractor. To assure compliance with the weight, volume, environmental stress, and fuzing performance requirements, numerous technical trade-off studies were conducted. Reliability specifications required the incorporation of specialized

techniques in the design and fabrication processes. Design-to-cost and value engineering have been major considerations in the development of the Patriot fuze. Those estimates are reviewed and updated continually. The latest review indicates that the unit cost in production will be within the cost estimated in 1973.

HDL supports the flight-test program by providing fuzes, specialized test equipment, and post-flight data analysis. The flight-test program comprises three phases of tests at White Sands Missile Range. The first phase, the proof of principle test phase, has been successfully completed. The second phase, the engineering flight-test phase, is currently nearing completion, with favorable test results to date. The final phase, the 25-missile DT/OT-II test phase, began in August 1979.

Facilities at the HDL Blossom Point Test Area (see fig. 21) are being used to conduct fuze-target encounter experiments to complement the missile flight tests and to develop fuze-to-target and fuze-to-jammer encounter models. Fuze data recorded from these runs are velocity scaled to expected encounter velocities to simulate actual missile/target conditions. Data and analysis from these efforts will be a significant input to the assessment of the single-shot kill probability of the Patriot air defense system.

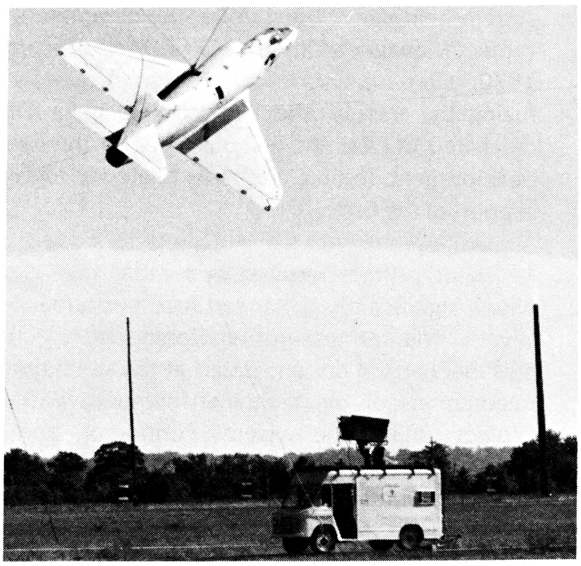

Figure 21. Blossom Point Test Area.

Reliability efforts continue to be a major segment of the activities of both HDL and the fuze support contractor. A long storage life requirement necessitated special studies to assure that components would not degrade or catastrophically fail in storage. Two high-reliability lines are being established for the manufacture of the thick-film microcircuits which make up roughly 50 percent of the fuze electronics. A single large-scale integrated (LSI) silicon-on-sapphire circuit has been developed to replace an assembly of integrated-circuit logic elements; this development will enhance reliability. Associated special test methods and test hardware are being developed in parallel with and in support of the LSI effort. Additionally, a new high-reliability transmitter has been designed and qualified during this past year. Fuze reliability has been significantly enhanced by these efforts. In addition, failure analysis and analytical investigation of new or nonstandard components receives a significant share of the program effort.

In-house and contract efforts are under way in Production Engineering Planning (PEP) of the XM818 fuze. PEP tasks include identification and design of special tooling and special test equipment, as well as development of qualified second-source suppliers of critical fuze components and subassemblies. In FY78, HDL designed and fabricated an Automatic Factory Acceptance Test Set. Acceptance testing of a production fuze at the factory will take approximately two minutes. This contrasts with the 5 man hours that are required to run a comparable roster of separate measurements when the manual test is used. HDL is also currently designing the fuze portion of the sophisticated automatic factory tester for the missile. In both testers, accuracy and precision are improved by the elimination of human error and by the addition of automatic self-check sequences. These testers, a number of module testers, and a quantity of other special tooling and special test equipment will be fabricated and proven-in as part of the multimillion-dollar Initial Production Facilities program that was initiated this year.

M735 Proximity Fuze. The 8-in. (203-mm) nuclear projectile (XM753) requires a highly accurate and reliable proximity fuze. Engineering development of the M735 fuze was started in FY75. In FY78, the first phase of DT-II was completed and the fuze was type classified for procurement. In FY79, DT-II testing of the fuze was completed, except for some joint tests with the Department of Energy, which is developing the warhead components. The first procurement contract was let late in the fiscal year.

Fuze Description. The fuze consists of (1) a dual-channel target sensor, (2) a two-out-of-three logic multiple-channel programmer for in-flight safety and arming and sensor turn-on, and (3) a power supply that provides handling safety, power for arming and warhead electrical functions, and power for the fuze sensor. One noteworthy feature of the fuze design is the removable forward section containing the power supplies and memory/timing portion of the programmer. This section can be stored and set off the projectile for safer handling and storage.

The fuze is shown in figure 22, a cutaway view, and figure 23, an exploded view; each view shows the electronics and the titanium mechanical structure. The fuze consists of three major assemblies: the forward assembly, which contains power supplies and programmer memory/timing circuits; the center assembly, which contains the target sensors; and the rear assembly, which contains programmer power output, decode, and arming decision circuits.

The target sensor for the M735 fuze is a dual-channel, highly accurate ground-proximity sensing system. The programmer for the fuze is a three-channel, accurate, reliable turn-on timer requiring two-out-of-three channel coincidence to provide arming outputs to the warhead and target sensor. The programmer uses a resistor-capacitor (RC) oscillator calibrated during setting and a complementary metal oxide semiconductor (CMOS) scaler to achieve 0.1-s setting resolution. The oscillator/ scaler of each channel is contained in a custom large-scale integrated circuit (LSIC). The memory and the main counting function are provided by the

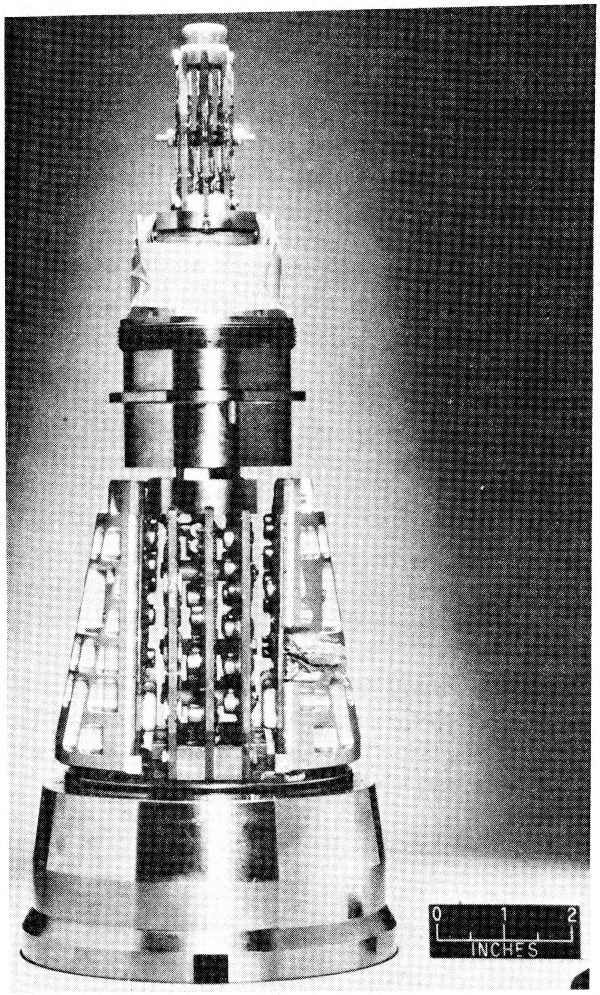

Figure 22. M735 fuze (cutaway view).

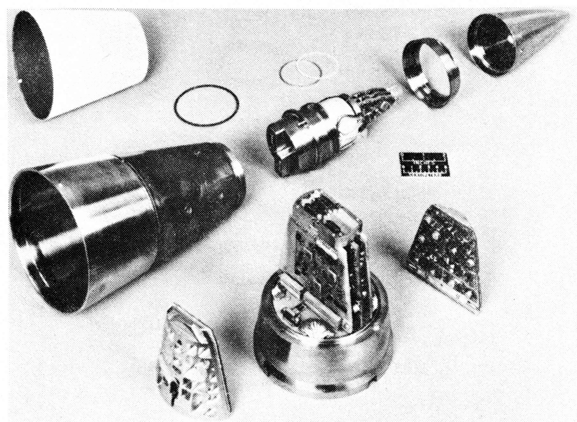

Figure 23. M735 fuze (exploded view).

metal nitride oxide semiconductor (MNOS) counter/memory IC developed by HDL for the M587E2 electronic time fuze. The output of the MNOS counter/memory starts a 12.0-s auxiliary decode counter that generates the arming time intervals. The decoded outputs of the counters are combined in two-out-of-three coincidence circuits to generate the required output signals, thus improving safety and reliability. All the decision circuitry and the decode counter of each channel are contained in another custom LSIC replacing 11 standard CMOS IC's.

The programmer is divided into two sections: (1) a removable nose section, containing the three time-base oscillators, scalers, and MNOS counter/memories, and (2) the projectile section, containing the decode counters, decoders, arming decision circuits, and output circuits. The setter provides the nose sections with the desired in-flight arming time.

PS416 Power Supply. The PS416 power supply for the M735 fuze (see fig. 24) provides arming and warhead electrical-function power, fuze sensor power, and handling safety.

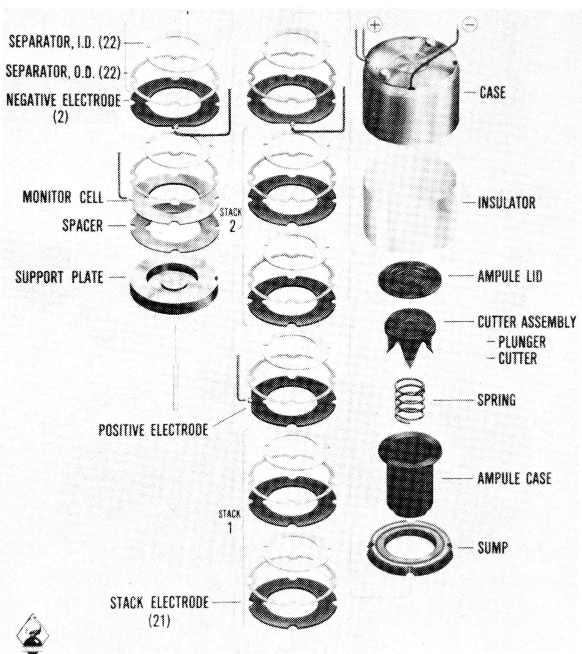

Figure 24. PS416 power supply.

Electrolyte is stored in a copper ampule that also contains a cutter-weight spring assembly for piercing the ampule during setback, thus activating the battery. Handling safety during projectile preparation and ramming before gun firings is provided by the dashpot action of the ampule assembly, which requires a shock impulse of at least 4 g-seconds (or a sustained load of 500 g) to pierce the ampule.

A problem discovered in the M735 fuze DT-II tests is a failure of some bottom batteries to deliver the required pulse current at cold temperatures in high zone firings. Because the top battery functioned properly in DT-II tests, the DEVA-IPR found the small degradation in system reliability acceptable.

XM38 Fuze Setter. The XM38 fuze setter is designed to set in-flight timing and option-selection data into the M735 fuze nose section just before the nose section, containing all programmer memory/circuits, is inserted into the front panel of the setter (see fig. 25). The operator can then initiate several automatic test, set, and verification sequences that feed back status information from the fuze nose section to the setter status readout, a light-emitting diode (LED) alphanumeric display.

In FY77, the setter underwent a major circuit change to accommodate the fuze modification that incorporated custom LSIC's. Also, following users' suggestions, an outer case was added to the setter package for abrasion resistance in the field. Changes to improve performance in electromagnetic radiation, sun-shielding, and night-lighting were also included.

In FY78, because of delays in the XM753 projectile program, DT-II evaluation of the setter was delayed, at HDL's request, to permit an additional cycle of package redesign to reduce size, weight, and cost, and to add external power capability to the setter; this external power would supplement the internal rechargeable power supply, particularly in extremely cold environments, where more frequent recharging of the power supply would be required. All the above changes were in

Figure 25. XM38 fuze setter.

response to user inputs, after review of earlier setter designs.

The final DT-II evaluation of the setter in early FY80 should result in type classification by mid-FY80 for procurement.

M735 Fuze Telemeter. The M735 telemeter monitors the performance of the fuze system in-flight by transmitting fuze output and diagnostic data to ground receivers.

The telemetry system is designed to be gun rugged, to operate over the temperature range from –37 to +57°C, and to be reusable after recovery when it is fired on a special parachute recovery projectile designed by ARRADCOM for this program. Both the telemeter and parachute recovery projectile performed well in over 50 fuze firings during FY77. During FY78, in 87 fuze firings (without parachute recovery), the telemeter performed properly except for seven transmitter-related failures which have been diagnosed and corrected. During FY79, an additional 76 fuze firings with telemetry were conducted with little loss of data.

Program Status. The M735 fuze was designed, built, and tested electrically and structurally during the first two years of development. During this period, the design was changed to incorporate improvements based on test results and changes required to mate the fuze with the projectile and with warhead electronics.

By the end of FY76, the fuze design was essentially complete, as evidenced by a successful initial evaluation of the fuze performance in extreme-condition gun firings during and after exposure to adverse environments. During FY77, a final group of 50 development fuzes was fabricated and gun-fired over a representative range of environments.

These fuzes performed excellently in laboratory and gun-firing tests, revealing a few problems which were corrected before the start of DT-II fabrication.

The DT-II program to evaluate a total of 160 fuzes and 12 setters began in the third quarter of FY77 and has continued through FY79, in step with the warhead development and test program. In the DT-II program, the M735 fuze and the XM38 fuze setter are being evaluated by the US Army Test and Evaluation Command, under the direction of the Army Materiel Systems Analysis Agency. The results of tests of 74 fuzes in the 160 fuze DT-II test program were presented to the DEVA-IPR in April 1978. Formal type classification took place in August 1978.

XM749 Proximity Fuze. The new 155-mm nuclear projectile (XM785) requires a highly accurate and reliable proximity fuze. In the ERDA/DoD Phase II Study, in 1976, HDL proposed a fuzing system much smaller in total volume than the M735 fuze

above because of the limited space available for fuzing.

The fuze will consist of a target sensor system and a two-out-of-three channel programmer. A nose section, containing most of the three-channel programmer components and power supplies, will be stored separately and set off the projectile for safer handling and storage.

A multichannel gun-rugged telemeter must be developed to monitor the performance of the fuze system in-flight, by transmitting fuze output and diagnostic data to ground receivers.

The XM749 fuze programmer will be safety checked and set by a fuze setter, which will be based on the XM38 fuze setter for the M735 proximity fuze.

During FY78, advanced development was started, consisting principally of negotiations between DOE and DoD design agencies on volume allocation and interface definition. Alternative packaging concepts are being actively considered. Fuze system studies and preliminary layouts are being made to support the alternative concepts.

Engineering development started in FY79, after a baseline volume and electrical interface were established between DoD and DOE. The initial structural design has been finished, and models fabricated and gun-fired. A contract has been let to develop the fuze circuitry and packaging, based on HDL concepts and initial electrical design.

M587/M724 Electronic Time Fuze and M36 Fuze Setter. The M587/M724/M36 electronic time (ET) fuze system is the Army's first major effort to adopt digital electronic timing to supplement mechanical timing in fuzes for artillery projectiles. The ET fuze system was type classified as logistics control code A (LCC-A) in January 1979 following a most successful DT-II/OT-II program in which all safety criteria were satisfied, and 98-percent reliability and excellent accuracy were demonstrated. Contracts for initial production and design of manufacturing facilities were awarded in September 1979. Figure 26 shows the M36 fuze setter setting the M744, an inert training fuze which can take on the external configuration of either the M587 or M724 by the addition or removal of a booster cup.

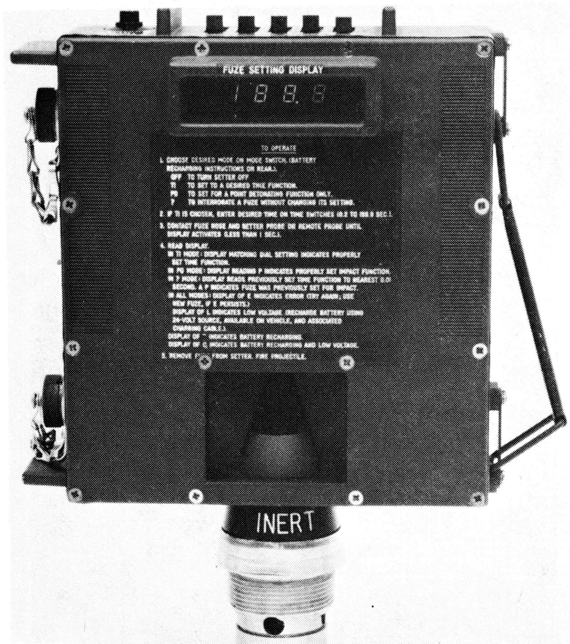

Figure 26. M36 fuze setter.

The introduction of the ET fuze system into the Army inventory will result in the following advantages.

- This system will permit the electronics industry to serve as an alternative mobilization base for time fuzes.
- The system will use manufacturing technologies having a strong downward cost curve in the civilian economy (e.g., electronic watches, hand-held calculators).
- A single fuze is used with a wide variety of 105-mm, 155-mm, 175-mm, and 8-in. weapons and projectiles (including rocket assisted).
- A rapid, simple setting system permits nondestructive stockpile surveillance and has demonstrated (in HELBAT VI and VII) compatibility with direct setting by field computer.

- Increased accuracy will result from use of an electronic oscillator which is calibrated during setting (the standard deviation is less than 0.100 s).

Manufacturing methods and technology (MM&T) activities directed at reducing the cost of the several special-purpose IC's employed in the fuze have resulted in the simplification of the two hybrid IC's and the consolidation of the two silicon monolithic IC's into a single chip and package.

In the oscillator IC, silicon monolithic chips handled in tape carriers are tape automatic bonded (TAB) to ceramic substrates containing precision thick-film resistors. In a single solder-reflow process, each ceramic substrate has the semiconductor chip, a lead frame, and four ceramic capacitors attached to it. The completed substrates are subsequently encapsulated in a metal can to provide shielding. Figure 27 shows that the new oscillator (shown uncased on the right) is considerably less complex than the original oscillator.

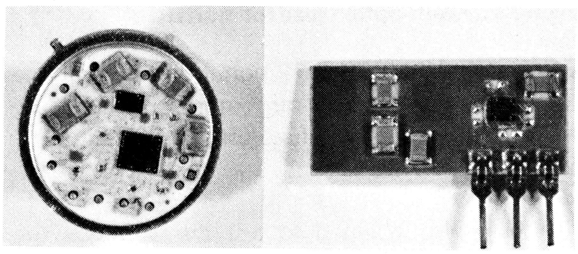

Figure 27. Oscillator hybrid circuits.

In the interface hybrid circuit two silicon monolithic chips are attached by automatic wire bonding to a substrate bearing thick-film resistors, a ceramic capacitor, and a lead frame. The resultant assembly is then injection molded to produce a 14-lead double-width dual-in-line package. A set of multi-image screens permits 20 substrates to be simultaneously processed on a single ceramic sheet. Figure 28 shows that, although the new interface hybrid (shown uncased on the right) is a pin-for-pin replacement for the original IC, it is a much less complex device to fabricate.

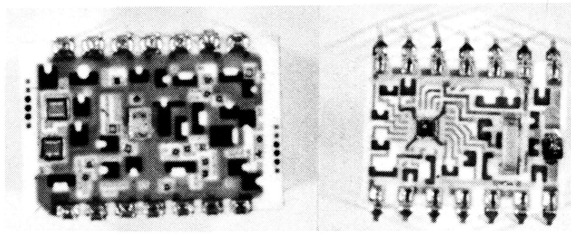

Figure 28. Interface hybrid circuits.

In the third MM&T effort, a combination timer chip (combining all the functions of the counter/memory and the scaler/logic IC's as well as those of two discrete zener diodes) is wire bonded onto lead frames and molded into a 16-pin dual-in-line plastic package in a multicavity mold.

Approximately 300 M587 fuzes incorporating all the newly developed IC's and a smaller transformer onto a single printed-circuit board were fabricated and prepared for validation testing. Figure 29 compares the E-head of the new fuze design (shown on the right) with the type-classified design.

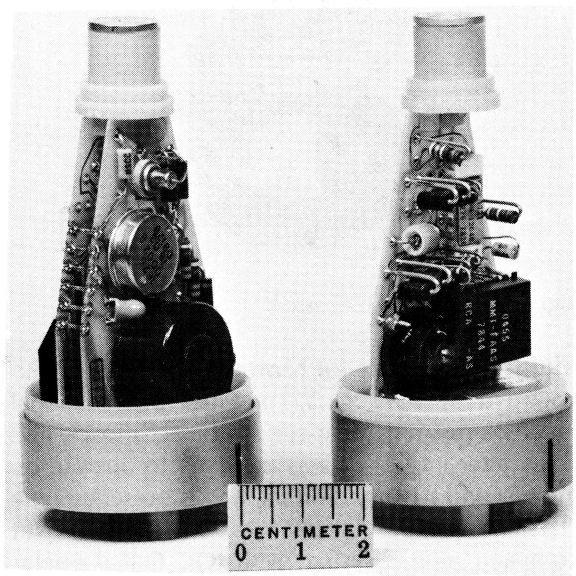

Figure 29. M587 E-heads.

Activity is also under way to halve both the cost and the size of the M36 fuze setter by employing microprocessor technology. The contractor's preliminary concept for the M36E1 is shown in figure 30.

Figure 30. M36E1 fuze setter.

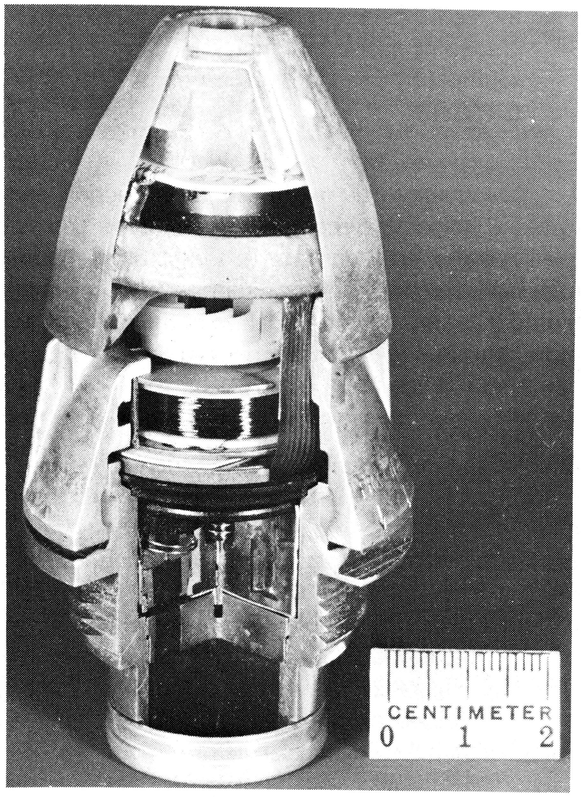

Figure 31. Multi-option fuze for mortars.

Multi-Option Fuze for Mortars. The M734 multi-option fuze (MOF) (fig. 31) provides four functional modes: proximity, near-surface burst, impact, and delay after impact. It was designed to operate on the 60- and 81-mm mortars, and is presently type classified (TC) for use on the 60-mm lightweight company mortar system with IOC (initial operational capability) scheduled to be achieved in FY80.

Interest has been shown in using the MOF on various foreign mortars. US Army DT/OT-II testing is now under way using the M734 MOF on the UK 81-mm mortar. Type classification on the UK mortar is expected in FY80. If this test program is successful, the UK 81-mm mortar will become the new US improved 81-mm mortar system; the M734 MOF will be the fuze used on both the 60- and 81-mm US mortars.

It is also planned to test the MOF on the present US 81-mm mortar. The MOF requires an adaptor to be used on the present US 81-mm mortar and thus acquires new nomenclature in that role: the XM741 MOF. Certification testing of the XM741 is scheduled for FY80.

A program to develop a low-cost practice fuze based on the MOF was begun in the last quarter of FY79. This practice fuze (the XM745) will use the M734 safety and arming system, including the turbine/alternator. Thus, it will have the same dual environment sensors as the M734. The XM745 will be designed to function in the impact mode r ardless of its set mode. This will allow troop practice, including mode selection, using a very low-cost

fuze. Type classification on the 60-mm mortar is scheduled for FY81.

NATO Sea Gnat Fuze. A consortium of five NATO countries—the United States, the United Kingdom, West Germany, Norway, and Denmark—is developing a complement of decoy rounds to protect ships from incoming missiles. One of these rounds, a rocket, requires a remotely set time fuze for effective deployment. HDL is developing an inductively set digital time fuze to meet this need. The baseline design of the fuzing system has been completed and is undergoing development testing which is scheduled to be completed by December 1979. DT-II testing is scheduled for the spring of 1980.

The US Navy's MK36 launcher is used for the Sea Gnat round. This launcher uses an inductive link for firing the round. This link is shared and used to transfer information to the fuze, thus minimizing modifications to the launcher. The desired time setting for the fuze originates in the combat intelligence center and is sent via hardwire to a point near the launcher. Here it is converted to serial data and transmitted to the launcher coil. A pickup coil on the round picks up enough of a signal to turn on the round electronics and store the desired time data. When the round is fired, the desired time delay is generated and the round is deployed.

To reduce the development cost and program risk, previously developed subassemblies for other applications are being modified and used wherever possible. The electronics design is based on a custom CMOS IC previously developed by ARRADCOM for the Beehive fuze; the battery is a modification of the PS123; and the S&A is a modification of the 2.75-in. rocket S&A.

This year, 25 rounds have been fired. The S&A's and thermal batteries worked properly in all cases. Interface problems with the round have required modifications of the electronics; these modifications will be completed and 25 additional rounds are expected to be fired by the end of the year.

The Sea Gnat program is being managed by the NATO Sea Gnat Project Office at the Naval Electronics Command, and the technical management is provided by the Naval Research Laboratory.

EX18 Arming Safety Device for 5-in. Guided Projectile. The EX18 arming safety device (ASD) uses setback and muzzle exit signatures for arming. The device was described in detail in the FY78 posture report. The ASD is being developed for the Naval Surface Weapons Center (NSWC) at Dahlgren.

A total of 100 engineering development ASD's were received from the ASD contractor, and the ASD's were modified, retested, and prepared for final delivery at HDL. ASD's were delivered to NSWC for environmental and safety qualification tests currently under way at the Dahlgren facility. ASD's were delivered to the projectile prime contractor for installation in projectiles scheduled for telemetered flight tests and instrumented HERO (hazards of electromagnetic radiation to ordnance) tests in the next fiscal year. The remaining interface issues regarding warhead cable termination at the ASD and single-point grounding were resolved with the prime contractor.

Developmental efforts continued to improve the consistency of the muzzle exit lock and to characterize by accelerometer measurement the output of the piston actuator that removes the lock. Work continued to explore bridgewire substitution in the MK96 detonator to eliminate the present tungsten bridge which is subject to corrosion.

The status of the design and the technical data package were reviewed with NSWC. The follow-on contract for ASD development was let by NSWC based on tasks recommended jointly by HDL and NSWC. HDL is continuing in-house studies of potential problem areas and is providing technical direction of the contractor effort.

Navy Fuze Function Setter. Development of the Navy's semi-active laser-guided projectile (SALGP) has generated a requirement that information be

provided to the projectile just before firing. The fuze/function setter (FFS) system has been designed to receive data from the shipboard fire-control system, transmit the message via an inductive data link to the SALGP, and then verify that the message stored in the SALGP is correct. The FFS system consists of a setter control unit (SCU) which will be developed by Lockheed Electronics, a setter unit (SU), and a transmitter coil, both of which have been developed in-house under the sponsorship of NSWC at Dahlgren. The receiver circuit in the SALGP was originally designed in-house, and is presently being pre-production designed at Martin-Marietta.

The Navy has selected this system as the standard method for setting all future projectiles developed for the MK 45 5-in. and MK 71 8-in. gun mounts. The hardware delivered will be used to support these developments and to support the shipboard firing tests of SALGP rounds scheduled in 1980.

Five SU's, 10 molded transmitter coils, and a technical data package were delivered to NSWC early this year, thus completing the HDL effort on this program.

Procurement and Procurement Support

M817 Target Detecting Device. The M817 target detecting device (TDD) replaces the Navy MK 15 TDD and is part of the improved Chaparral Missile (MIM-72C). It was developed by HDL under the sponsorship of the Chaparral PM.

Deliveries on three production contracts for 1325,[5] 341,[6] and 2118[7] with International Signal and Control Corp. (ISC) have been completed. LaBarge Inc. was awarded a contract[8] for the FY78 quantity of 948 and an add-on to this contract for the FY79 quantity of 888. The First Article Approval Sample was delivered in June 1979 and conditionally accepted. Because of a move of the manufacturing facility, delivery of the first lot was delayed until late September 1979.

A successful Initial Production Test of the MIM-72C missile with TDD's manufactured by ISC took place between the fall of 1978 and the spring of 1979. A limited number of successful sled and flight tests of LaBarge-manufactured TDD's have taken place.

M732 Proximity Artillery Fuze. Contracts for a total of 852,700 M732 fuzes were awarded in prior fiscal years at an average price of $60 per fuze to fulfill supply requirements. The prime contractor, Lockheed Electronics Co., delivered 219,000 fuzes (17 lots) in FY79. Results of field firings of ballistic lot acceptance samples selected from each of the lots substantiated that fuze performance meets the requirements of the ROC (required operational capability). The balance of the contract quantity, 634,000 fuzes, will be delivered in FY80.

The FY79 and subsequent procurements of the M732 will be contracted to industry through the Armament Materiel Readiness Command (ARRCOM) with ERADCOM and HDL providing limited engineering and quality assurance support.

The Procurement Contracting Officer functions on HDL-awarded contracts for M732 fuzes and fuze components were transferred to ARRCOM in July 1979 to coincide with transition from the Armament Research and Development Command which took place in the same month.

M734 Multi-Option Mortar Fuze. The M734 fuze is designed for use on the M720 60-mm high-explosive cartridge of the lightweight mortar system. The first procurement for stockpile is being accomplished by three multi-year (two-year), fixed-price contracts awarded in FY78 that also provide for the design, construction, and prove-out of Initial Production Facilities.

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[5] *Contract DAAG39-76-C-0030.*

[6] *Contract DAAG39-77-C-0116.*

[7] *Contract DAAG39-77-C-0162.*

[8] *Contract DAAG39-78-C-0017.*

Alternators manufactured by Alinabal Corp.[9] and amplifiers produced by Motorola, Inc.,[10] will be provided as GFM to the fuze assembly contractor, Eastman Kodak Co.[11] Unit costs at the time of award were $41 for the FY78 procurement of 110,000 fuzes, $27 for 330,000 FY79 fuzes, and $11 million for the IPF system. Delivery of the first fuze lot is expected in November 1979.

Alternators were delivered on schedule, but difficulties were encountered in the production of amplifiers, and deliveries slipped six months. Catch-up schedules are in effect, and delivery of the last lot of fuzes should only slip two months. Cost growths associated with government failure to deliver GFM are being minimized by benefits from an active Value Engineering Program.

M735 Proximity Artillery Fuze. The M735 proximity artillery fuze was type classified standard in August 1978. The Project Manager, Nuclear, authorized and funded the first buy of the M735 projectile fuze for the new 8-in. nuclear projectile (M753) in January 1979. In anticipation of that release, contracts had been awarded for the in-line and final test equipment, gauges, long-lead-time parts, and some unique components.

A Request for Proposal has been issued for the procurement of the first buy of fuzes, trainers, spares, and telemeters. A letter contract[12] was awarded in September 1979, to be made definite in the first quarter of FY80.

A detailed review of the development baseline technical data package and a physical configuration audit have been completed. The first group of drawings have been signed and placed under Configuration Management Control. The remainder of the technical data package is scheduled to be signed before the production contract award.

A production-type tester for the fuze power supply (PS416) was developed at HDL and is currently under final evaluation. Power supplies are scheduled for procurement in FY80.

The XM38 fuze setter, which is designed to set the fuze and perform some basic fuze status checks in the field, is scheduled for DT-II tests in the first quarter of FY80, with type classification scheduled for January 1980. Contract award for the first buy of setters is scheduled for March 1980.

Since the logistic support plan for the projectile does not provide for repair of fuzes in the field or at depots, procurement of spare fuzes has been authorized. The Integrated Logistic Support Plan for the setter is being prepared by PM-NUC based on HDL inputs.

Setters and specialized components for the complete fuze program will be procured with FY80 funding. Award of the second-buy fuze procurement contract is scheduled for the first quarter of FY81.

M724 Electronic Time Fuze and M36 Setter. The M724 ET fuze system is designed for artillery projectiles, both high explosive and cargo rounds. It is a high-precision electronic time fuze that is electronically set by the M36 fuze setter. Contracts for the first procurement of the system were let during September 1979. The procurement plan required that the fuze, power supply, and M36 setter be purchased by means of competitive, fixed-price, multi-year, split-award contracts, with the power supplies being GFM to the fuze contractor. Except for the setter, Initial Production Facilities are to be constructed in conjunction with the first-year production (FY79) and used for all remaining contractual delivery requirements (FY80/81).

Eastman Kodak Co.[13] was awarded the entire fuze production contract and half the setter production; Cartwright Engineering[14] was awarded the second half of the setter production. Power supply awards were split between Eagle Picher[15]

[9] *Contract DAAG39-78-C-0130.*

[10] *Contract DAAG39-78-C-0125.*

[11] *Contract DAAG39-78-C-0126.*

[12] *Contract DAAK21-C-0148.*

[13] *Contract DAAK-21-79-C-0135 and 0114 for setter.*

[14] *Contract DAAK-21-79-C-0115.*

[15] *Contract DAAK-21-79-C-0133.*

and Accudyne.[16] The total value of production contracts is $81 million. Fuze and setter unit prices are as shown in table 1.

Table 1. Unit Prices for Fuze and Setters

Component	FY79($)	FY80($)	FY81($)
Fuze	89	81	73
Setter (Eastman Kodak)	3,749	2,200	-
Setter (Cartwright)	2,773	2,654	-

Production Base Support

In FY79, nine new Production Base Support orders were received, adding a total of $1,253,000 to HDL's Army Industrial Fund (AIF). (An additional $19,805,000 of non-AIF funding was provided for HDL to purchase production equipment for the M724/M587 fuze Initial Production Facility, for internal HDL facilities, and for contracted manufacturing methods and technology effort). The new AIF orders can be categorized as shown in table 2.

Table 2. New AIF Orders

By sponsor	No.	$ Value
DARCOM	2	110,000
ERADCOM	1	4,371
ARRCOM	4	979,000
ARRADCOM	1	100,000
AMMRC	1	60,000

By fiscal class	No.	$ Value
4211 (PIF, Ammo, GOGO)	1	100,000
4212 (PIF, Ammo, GOCO)	1	600,000
4250 (MMT, Ammo)	4	479,000
5297 (MMT, Elx)	2	14,371
5397 (MMT, Other Support)	1	60,000

[16] *Contract DAAK-21-79-C-0134.*

Initial Production Facility, M734 Multi-Option Fuze. In conjunction with the first procurement contracts for the M734 multi-option fuze, each of the selected contractors is required to design and construct an Initial Production Facility (IPF) as follows.

Motorola, Inc.	amplifier assembly IPF
Alinabal Corp.	alternator assembly IPF
Eastman Kodak	fuze assembly IPF

The construction is to be concurrent with the first year production of hardware, and the entire second year delivery quantity is to be produced on the IPF. Following prove-out, a technical data package is to be provided which will allow the IPF to be reproduced as necessary to satisfy mobilization base requirements.

The level of mechanization of each IPF is limited to those assembly, inspection, and testing stations on the production line which self-amortize in two years when the machinery is operated at design rate. The design rate for the fuze IPF is 100,000 units per month. To account for attrition of GFM, the rate for the amplifier and alternator IPF's is 106,000 units per month. These rates are based upon plant operation on a 1-8-5 basis (one eight-hour shift, five days a week) in a 20-day month with an 80-percent availability of machinery.

Contracts require that the IPF's be designed using standard commercial equipment in a fashion that assures low costs, whether operating at design rate or at the lower rates associated with peacetime production for stockpile. Contractor-owned equipment dedicated to the IPF is employed wherever possible. Each contractor's IPF is on schedule and within budget; the total IPF system cost is $11 million.

Initial Production Facility, M587/M724 ET Fuze. In conjunction with the first procurement contracts for the M724 electronic time fuze, each of the selected contractors is required to design and construct an IPF as follows.

Eastman Kodak	fuze IPF
Eagle Picher	power supply IPF
Accudyne	power supply IPF

IPF's are to be constructed in conjunction with the first-year production on each contract and will be used for all remaining contractual delivery requirements (FY80/81). The IPF's are to be capable of fabricating 60,000 power supplies on a 1-8-5 basis. A higher rate for the power supply facilities will accommodate attrition of GFM. Upon completion of the IPF, technical data packages are to be delivered which would allow duplication of the facilities in the numbers needed to satisfy mobilization base requirements during wartime.

The total value of the IPF contracts is $26 million. Prove-out of the IPF's will be performed on a minimum of 345,000 power supplies at each contractor, and on 627,000 fuzes. These quantities represent FY80 and FY81 production. Prove-out may be increased if the IPF's are available in time for FY79 production, or if option quantities are exercised by the government.

MM&T Program on Turboalternators. The PS602 power supply for the M734 multi-option mortar fuze is a wind-driven turboalternator. A pilot production facility to make alternator parts has been completed under a manufacturing methods and technology (MM&T) program. The equipment developed has been transferred to the IPF to manufacture parts for the initial production buy.

A summary of machinery and equipment that resulted from the MM&T program follows.

- A special machine was fabricated to produce "crimped" miniature bearings; 40,000 such bearings were produced.

- An eleven-station progressive die was designed and fabricated to produce alternator housings. A nine-station progressive die was designed and fabricated to produce alternator end-plates. Approximately 12,000 of each part were produced.

- A multiple-cavity mold was fabricated to produce shaft magnet assemblies by molding nylon between the parts, thereby locking them together.

- A special machine was designed and built to straighten, cut off, broach, and hollow mill shaft blanks. Although several thousand blanks were successfully produced, modification of this machine is planned during the IPF to improve the production rate.

- A Kinefac machine system was built to bowl feed-shaft blanks through two rollers which knurl, roll races, and roll threads to produce finished alternator shafts.

- A coil winding machine was designed and built to wind a coil of wire around the alternator bobbin. A corollary 12-station progressive die was fabricated to produce bobbin-contacts. The coil winder also resin-coats the contacts for electrical insulation. A production rate of 300 finished coils per hour was achieved.

The primary benefit derived from this MM&T effort is the advance in the art of fabricating low-cost bearings, shafts, and associated turboalternator parts. Actual production-capable machines (rather than pilot or prototype devices) were designed and built and then physically transferred to an IPF on which production for the M734 fuze will be carried out. In some cases, simple replication of the MM&T machine is all that will be required.

Although the effort was carried out specifically for the M734 fuze, the resulting facility and certainly the new manufacturing technology will be applicable toward turboalternators for other mortar, projectile, or rocket electronics.

PS127 Liquid Reserve Battery for M587/M724 Fuze. The PS127, a lead/lead-dioxide/fluoboric-acid reserve battery with parallel-plate construction, provides power for the M587/M724 electronic time fuze. A contractual effort is providing

process and pilot facilities for selected manufacturing processes. These are tungsten-inert gas (TIG) welding the copper ampule, punching electrodes, edge painting electrodes, and stacking and parting electrodes. The TIG welding pilot-line produced 7000 ampules and was a source for a battery production that successfully powered the M724 fuze through type classification. Pilot-facility tooling to punch electrodes and to paint, stack, and separate parts is in a matrix configuration. The configuration, eight parts connected by narrow tabs to the carried strips, yields multiple batteries with each manufacturing step.

MTT Effort on Two-Channel Telemeter for Use in a 3-in. Spin Air Gun. The development of a two-channel telemetry system for use in a 3-in. spin air gun or artillery simulator began in January 1979. Telemetry read-out will provide a necessary degree of precision and reliability unattainable with the read-out of electrical data through sliding contacts, which introduce intolerable electrical noise.

The telemeter will be a 3-in. diameter, 7-in. long, gun-rugged package that can be reused many times in the testing of conditioned power supplies. It will contain logic components for controlling the battery load program, i.e., applying and removing loads at fixed time intervals as opposed to using steady-state loads for the full test. The temperature-conditioned test battery will be plugged into the telemeter package and the unit turned on just before launch. An auxiliary supply, consisting of NiCd cells and a regulated dc-to-dc converter, will provide basic telemeter power, but will be supplemented by power from the battery undergoing test. A commercially available 1510-MHz transmitter will serve as the carrier oscillator. Test battery voltage and load current will be continuously monitored by two data channels (22- and 40-kHz subcarrier oscillators).

Benefits derived from the use of the reusable air-gun telemeter are as follows.

- It permits more and lower-cost acceptance testing of battery power supplies, although some field testing will always be necessary.
- It reduces the time between incorporation of battery design changes and the availability of results.
- It reduces data losses, particularly post-mortem data, associated with unrecovered rounds in field tests.

Modernization of Existing Mobilization-Base Electrode Plate Stock Facility. HDL provided engineering support to ARRCOM on a contract established to refurbish, modernize, and technically improve an existing mobilization-base electrode plate stock electroplating facility. The major objectives are to (1) increase production capabilities, (2) technically improve processing characteristics as well as the quality and storage characteristics of the product, and (3) generally upgrade (by replacement) worn-out components.

To accomplish these objectives, the following equipment has been installed, and prove-in of the entire system is planned for early October 1979.

- An automatic control system which will continually monitor and automatically control critical plating solution parameters within specified limits
- A vapor degreaser to improve base stock preparation
- A post-nickel anodization station to improve adhesion characteristics
- Larger conversion drums capable of operating at a higher temperature which will allow the line to operate faster, thereby reducing stock cost
- Strip guides, flake removers, stitcher, rectifiers, heat exchangers, contact roll wipers, deionizer, water filter, and beta gauge for general upgrading

Product Improvement

Product Improvement Program for M734 Turboalternator. The objective of the Product Improvement Program (PIP) for the M734 turboalternator is to replace the present material (permalloy), and to stamp the alternator housing and top plate, by means of a less costly material such as a silicon steel. Silicon steels are used in motor armatures and transformers; their cost is about $0.40 a pound as compared to permalloy, currently about $3.00 a pound. It has been estimated that replacing the more expensive material would decrease the overall production cost of the alternator by at least $0.25 per unit.

In the past year, alternators were fabricated from various silicon steels. Laboratory tests indicated that alternator parts fabricated from an M-36 silicon steel would provide approximately the same performance characteristics as the presently used alternator. The high content of iron in silicon steels may cause a corrosion problem; housings and end plates of this composition were therefore coated by electroplating. Accelerated storage tests indicate that the nickel coating is sufficient to avoid rusting. In the coming year, flight tests will be conducted to check the alternator performance in full-up fuzes in an actual field environment.

Reliability and Quality Assurance

Reliability and quality assurance (R&QA), as used here, denotes management responsibility over all activities contributing to the control of quality in production, design, and use of proximity fuzes. R&QA is primarily concerned with ascertaining that contractors control quality in their production and offer to the government for acceptance only those items that conform to contractual requirements. Thus, R&QA as a discipline contributes to the success of the HDL fuze mission.

Procurement Quality Assurance. All requests for procurement above $10K are reviewed for adequacy of quality-assurance provisions, whether for studies, research, supplies, or hardware. Approximately 162 procurement requests were reviewed and quality-assurance provisions were written for 52 contracts. Reliability, availability, and maintainability (RAM) and quality-assurance provisions that were developed for the M732 IPF have been revised and updated for use in procurement of the M724 fuze and components which was recently awarded. These contractors will be monitored by Product Assurance personnel in their roles as Product Quality Managers (PQM's). The PQM is the direct interface between the Defense Contracts Administration Service (DCAS) and HDL/ERADCOM for production contracts.

Reliability Technology. Several applications of reliability theory were carried out in FY79. The Patriot fuze reliability model was updated to include the latest design changes. In addition, a reliability assessment was done on the project. Reliability tests were performed on engineering development units. Reliability engineers continued to monitor the qualification of nonstandard parts; this qualification is almost complete.

A statistical analysis of the effect of tester measurement accuracy was done for the Patriot project. The same analysis was then used in the evaluation of production data for the M734 multi-option fuze.

Reliability engineering support was provided to elements of the XM445 fuze and a reliability assessment is now in progress. Also, the Ballistic Sampling Plan for the M732 artillery proximity fuze was updated.

Test Equipment Design and Support. The HDL Product Assurance activity provided tester support for in-house fuze development and contractor in-line and final acceptance testing. This support is provided by the review of tester designs proposed by contractors and by design and fabrication of test equipment in-house for the performance of specification-required tests.

In addition, HDL test-equipment personnel verified the acceptability of the test system's accuracy, stability, operability, calibration procedures,

operation procedures, change control record system, drawings, and interfaces. These personnel verified the equipment for use in performing acceptance testing for government procurement by observing demonstrations by the contractors.

Expert assistance was supplied to laboratories within HDL in the area of computer-controlled testers and hardware. Examples include the following.

- Parts for the microcomputer section of a fluidic gas-concentration sensor were designed and procured, and a prototype of a microprocessor-based, handheld data-acquisition and recording device was built. A final report has been written.

- Test-equipment personnel continued to participate on a design team for the new microprocessor-based Patriot testing system; the team's activities include specifying computer elements, designing interface circuitry, and developing computerized test techniques. The software package for the testers was written and debugged.

HDL test-equipment personnel are also designing and fabricating a computer-controlled tester for the M734 fuze. This tester will be dedicated to quality control and failure analysis testing.

Component Reliability. Electronic components are continuously tested to determine suitability for fuze use. The effects of electrical, mechanical, and environmental stresses simulating actual use conditions are assessed. Since many of the end items are gun fired, it is obviously advantageous to evaluate components in the same manner. The heart of the firing and recovery system is a field-emplaced 57-mm gun, oriented nearly vertically, which fires a specially designed ballistic test fixture with flight characteristics permitting nose-up flight both ascending and descending. In conjunction with a specially prepared landing zone in front of the gun, which is divided into coordinates, the system assists in quick location and undamaged recovery after the application of actual gun shock. All firing and recovery operations are performed by TECOM at Aberdeen Proving Ground. Only components which pass this test as well as the full complement of other electrical, mechanical, environmental, and reliability tests are qualified for fuze use. This year, as in the past year, over 2000 components were thus evaluated. A document which lists all such qualified components is prepared and distributed annually.

Component-reliability personnel assisted HDL fuze programs in various stages of system development and procurement by (1) recommending and specifying reliable components, (2) determining the trade-off of component reliability versus factors such as cost, (3) establishing component derating criteria, (4) determining valid component failure rates, and (5) performing component failure analysis. Extensive assistance was also given to HDL contractors with component failure or procurement problems. Because of its reliability orientation, the activity performing the above services also conducts the HDL GIDEP (Government-Industry Data Exchange Program). This program funnels into HDL all component reliability information gleaned from other members participants in the program. In turn, information obtained in HDL is entered into this system for recall by other members. During the past year, numerous inquiries and data were transmitted through this system in both directions.

Particularly noteworthy during the past year was the development and subsequent approval of a military specification for nonhermetic, solid tantalum capacitors, MIL-C-49137. Since nonhermetic, solid tantalum capacitors are in general use throughout the military and private industry, and since they are used in most if not all HDL fuzes, it is essential that an established specification be available for citation in technical data packages.

Simulation and Testing

Computer Simulation. The HDL PDP 11/45—Adage GP430, three-dimensional computer graphics facility was used for a number of simulation and data-reduction tasks over the past year. This com-

puter graphics system was used to provide engineers with a view of the operating characteristics of the device and/or system under study.

One of the first studies done this year was of the proposed three-dimensional vibration system under development in-house. This vibration system will simultaneously impose a defined vibration function along each of the three axes of the item under test. The project engineers required a mechanism to visualize the resultant displacements and accelerations of the tested item when various sinusoidal motions were imposed on each of the major axes. Figure 32 shows a typical display used by the engineers. Note that the user can dynamically change the frequencies and phase angles of the forcing functions. The user can also change the viewing angle and the speed of the simulation.

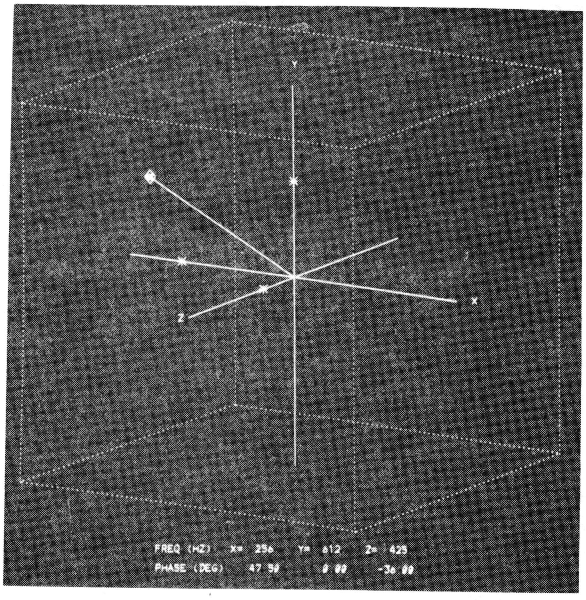

Figure 32. Three-dimensional vibration simulation.

A program was developed which modeled the mounting fixtures to be used to mount test items on vibration test equipment. The test fixture can be considered to be a spring-mass-damper system. Using numerical integration routines, various configurations of mounting fixtures were studied. Various types of X-Y plots were made based on the results of the computer runs. To help visualize the resulting motions, a program was developed on the PDP 11/45—Adage GP 430 system to display the actual motions predicted by the analysis program. Figure 33 shows one frame of a typical output from the display program.

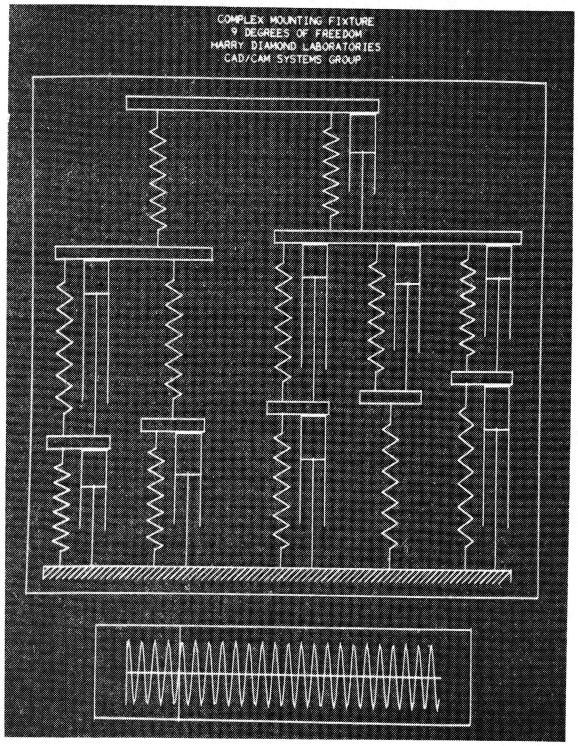

Figure 33. Model of vibration fixture.

A program was developed to assist the Field Test Group in reducing the voluminous film data recorded at Yuma Proving Ground and the Blossom Point test site. The films are projected onto the face of an Adage CRT, and by using a digitizing tablet to position a cursor on the CRT, the operator can quickly record the height of burst (HOB) of the fuze being tested. The program applies all the appropriate correction factors and prints out the final results for the operator's use. A sample from the training sequence of the program is shown in figure 34; a typical run is shown in figure 35. It shows computer-generated graphic information as well as a projected image of an artillery round undergoing an airburst. The computer program prompts the operator to identify particular points on the image. The operator either does this or else "picks" a box on the screen which explains why he could not.

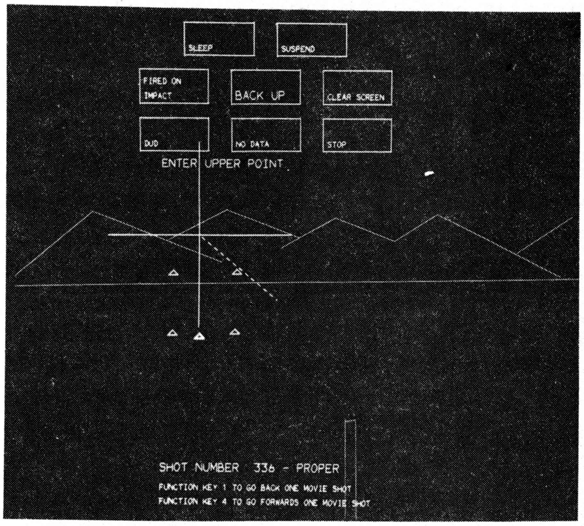

Figure 34. Training sequence for field-test data reduction.

The computer accumulates test and calibration data, combines these with separately entered statistical data, and converts them to a finished data report. Typical field tests often involve five cameras and several hundred shots. This technique permits a less skilled technician to reduce the data in one tenth the time (days instead of weeks) and do it more accurately. A later modification made to this program allowed those working on the Patriot Program to reduce their film data with this system.

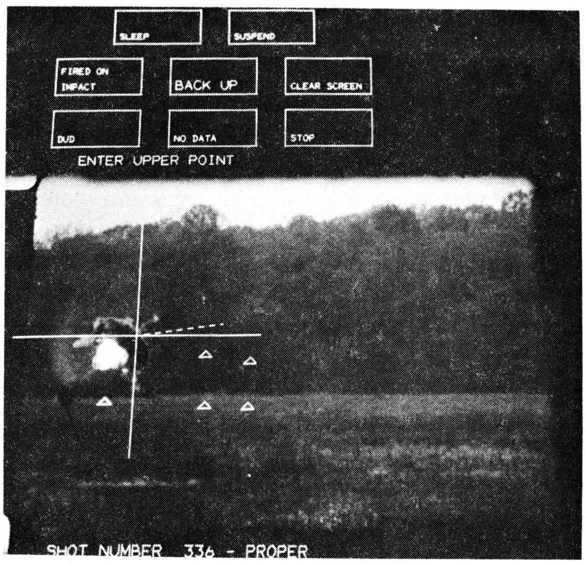

Figure 35. Height-of-burst data reduction.

Plans have been made to incorporate the newly procured Master Systems Controller, to be installed in FY80, into the simulation, CAD/CAM, facility. This new machine will coordinate the activities of many of the minicomputer-based systems currently being used within HDL. This new system will relieve the bottlenecks of the existing system by providing increased address space and more input/output ports.

Environmental Technology and Testing. During the past year, Patriot, Hawk, GSRS, G-76 hand-cranked generator, AN/145 TPD, ATRF, M-817/TDD, Sea Gnat, M734, M728, M732, M587, M735, JAMMER, XM741, Viper, and various experimental programs needed environmental technology and testing support. The programs were sponsored by ERADCOM, MICOM, TECOM, ARRADCOM, the Navy, and the Air Force.

Ballistic Simulation. HDL has a highly instrumented laboratory facility for ballistics simulation, to test fuzes or other components expected to perform or survive in a high-g environment. Simulators reproduce mortar, artillery, and short-tube rocket environments.

HDL's ballistic simulation capability has been enhanced by the successful completion of three 300-rps, 2-in. Table-Top Simulators. One tester, developed on a production base support (MTT) project, will remain at HDL while two testers, built with M732 project funds, will be installed in contractors' plants and will be used for lot acceptance (fig. 36).

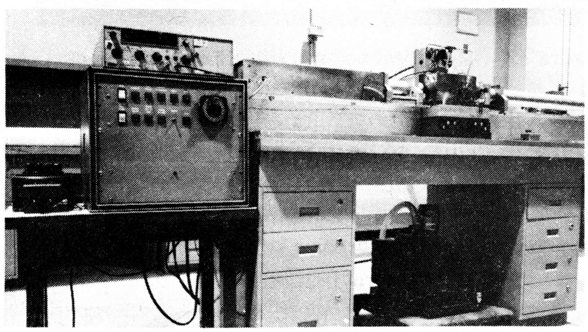

Figure 36. 300-rps, 2-in. Table-Top Simulator.

Modification of bearing mounts and the acquisition of higher speed motors have resulted in an increased spin capability in the 3-in. (762-mm) artillery simulator section to 250 rps (with no load).

A setback/drag simulator has been built which can test six fuzes at once in an environment that simulates the launch and flight of such weapons as Viper. Tests of the device indicate some spurious accelerations during (simulated) drag. This has caused a delay in the completion of this MTT project, but the tester is being used in actual fuze tests.

More realistic setback simulations require increased impact velocity and pulse duration. This results in a need for longer mitigators than are commercially available. For technical and financial reasons it is necessary to shape and assemble end-to-end mitigators of significantly different properties to form a composite mitigator. A theory and a set of procedures have been developed for composite mitigators which have led to a number of successful experiments. While not conclusive, the results have been very encouraging.

The high-pressure breech on the 4-in. (102-mm) gun has been moved downstream to improve efficiency. Experiments that indicate performance as high as 98 percent at velocities over 1000 ft/s (310 m/s) substantiate predictions and indicate that the gun is optimally configured for simulation applications.

The on-board recorder has been used to obtain acceleration-time data in a contractor's gas gun. On the third data shot, the recorder suffered irreparable damage. Preliminary data reduction of the first two shots supports analytic predictions.

Field Testing. The HDL Field Test Group (FTG) tests all types of HDL-developed fuzes, associated explosive devices, and electronic telemetry systems. Field-test equipment includes telemetry vans, an instrumented ground station, high-speed cameras, data-reduction devices, explosive loading and test facilities, a pole test facility, environmental chambers, drop towers, an encounter facility, and other necessary test equipment. Tests performed at the HDL Test Area at Blossom Point, MD, this year included firing, recovery, and disassembly of explosive loaded projectiles and fuzes for rockets, mortars, and cannon up to 105 mm in caliber, aircraft tests for light-scatter studies, flight tests for the BAFI project, Air Force drop and recovery tests, and Navy Sea Gnat tests.

HDL conducted and/or participated in about 25 ordnance item test programs this past year at Yuma Proving Ground, Aberdeen Proving Ground, the Arctic Test Center, Jefferson Proving Ground, the Naval Ordnance Test Station, Ft. Sill, Dugway Proving Ground, England, and White Sands Missile Range. These tests ran from several days to six weeks and required from two to six FTG personnel to process test items and/or operate the telemetry vans.

Environmental Simulation. HDL has available simulation, engineering, and environmental test services including temperature/humidity tests, conditioned shock-vibration tests, stress-strain tests, test planning and reporting, instrumentation support, and extensive mechanical fixture design. Over 100 environmental tests/tasks were conducted on fuzes, electromechanical subassemblies, and components in support of design validation and qualification, first article acceptance, engineering control sampling, failure investigation, and engineering development. Survivability tests conducted on printed-circuit boards from new Hawk and AN-145/TPD circuits demonstrated that resonance effects can be controlled by adhesive board damping material rather than traditional mechanical restraints. This resulted in design simplification and cost reduction.

A GenRad/4-channel Digital Control Test System (DCTS) was incorporated into the environmental simulation operations and was used to control most of the sinusoidal and random vibration tests. DCTS was also used to simulate the launch and transportation environments of the Patriot fuze by executing transient waveform control and shock spectrum synthesis tests which were derived from field conditions.

Modal testing software was installed on the DCTS and was used to rapidly identify modal parameters of the Patriot fuze. Up to 60 transfer functions were computed throughout the structure, from which resonance frequencies, deflection shapes, damping properties, and phase information were derived. Figure 37 shows the deflection shape for the first bending mode (544 Hz) of the cover plate of a Patriot fuze mockup. This project was supported by the AMMRC/MTT program.

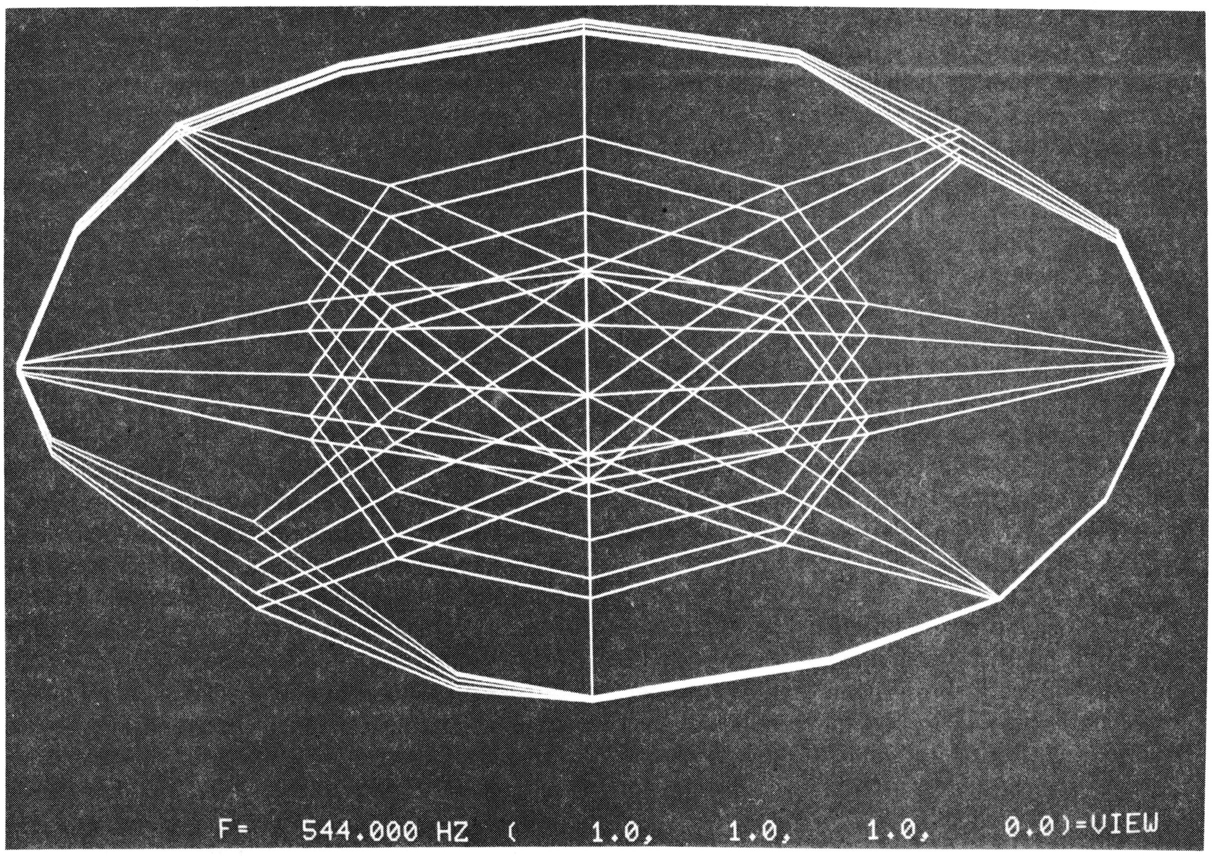

Figure 37. Modal analysis display—bottom plate, Patriot fuze, first bending mode.

nuclear weapons effects

Lead Laboratory for Nuclear Weapons Effects

As the DARCOM Lead Laboratory for Nuclear Weapons Effects Technology, HDL plans, coordinates, and manages the DARCOM nuclear weapons effects (NWE) program within ERADCOM and other DARCOM research and development commands. The program is designed to assure the overall survivability of critical Army materiel in an NWE environment. To ensure that this program is responsive to the overall Army needs and makes the best use of existing technical resources, HDL coordinates closely with a number of organizations: DA staff, DARCOM Headquarters, Training and Doctrine Command (TRADOC), Army Nuclear and Chemical Agency, Army Program/Project/Product Managers, DARCOM R&D Commands, and performing laboratories, as well as DoD agencies such as the Defense Nuclear Agency (DNA) and the Defense Communications Agency (DCA).

During the past year the program has continued to have a strong system orientation. Emphasis was placed on assessing the vulnerability of Army fielded and development systems to nuclear weapons and on the development of hardening techniques. Efforts were also directed at hardening for such emerging techniques as large-scale integrated (LSI) level solid-state electronics and fiber optics. A major new area this past year was the initiation of a program for development of a hardened tactical shelter.

Major managerial accomplishments this year included the following.

- HDL provided briefings to LTG Keith, the Deputy Chief of Staff for Research, Development and Acquisition, MG Bear of HQ DARCOM, and major Army Commands on the Hardened Tactical Shelter (HATS) Program; completed the program formulation and coordination; and established and staffed the HDL HATS Project Office which initiated the planned program.

- Responding to a request from US Army, Europe, an HDL team of nuclear experts assisted in a survey of the survivability needs of European computer facilities.

- HDL provided the Army member on the Joint Logistics Commanders' (JLC's) Ad Hoc Group on Logistic Support of Nuclear Hardened Systems. HDL staffed the Ad Hoc Group results thoughout DARCOM, and developed the DARCOM position on Ad Hoc Group recommendations for the March 1979 JLC meeting at which JLC directed the formulation of a JLC Panel.

- HDL provided the Deputy Chairman for the Army Nuclear Survivability Committee Secretariat.

- HDL provided the Army Technical Project Officer for French and German NWE Data Exchange Agreements (DEA's).

- HDL provided the US Coordinator and a Session Chairman for the Sixth International Symposium on Military Application of Blast Simulators, Cahors, France (June and July 1979).

- HDL participated with the Army Nuclear Chemical Agency in the development of revised nuclear criteria for the Quadripartite Standardization Agreement (QSTAG) and for use by NATO.

System Vulnerability Assessment and Hardening

The focus of the HDL NWE effort is the vulnerability assessment and hardening of critical military tactical and strategic systems. The work is performed under projects funded by the Army, DCA, DNA, and other agencies and is directed at increasing the survivability of these systems, in various combinations, to all nuclear weapons effects, including electromagnetic pulse (EMP), transient-radiation effects (TRE), system-generated EMP (SGEMP), thermal radiation, blast, and fallout.

Assessment and Hardening for EMP.

Multiple Systems Evaluation Program. The basic objectives of the Multiple Systems Evaluation Program (MSEP) have essentially been accomplished. These complementary objectives were (1) to formulate high-altitude electromagnetic pulse (HEMP) hardening recommendations or design guidance for fielded critical Army tactical systems and (2) to provide generic HEMP hardening technology for hardening of critical developmental systems.

MSEP was a major Army-sponsored program, designed to assure adequate survival of critical Army materiel during and after a nuclear exchange. Specifically, MSEP addressed the threat posed by the generation of HEMP to critical Army systems. These systems included (1) nuclear weapons delivery systems and (2) command, control, and communication (C^3) systems. Assessment of fielded systems not only provided an evaluation of vulnerability to HEMP, but also helped to develop hardening techniques. Moreover, the analysis and hardening tools developed in MSEP assessments can be transferred to system developers to harden these systems during the early phases of the materiel acquisition cycle. In previous years, assessments included the Pershing, Lance, M-109, and M-110 nuclear delivery systems. Also assessed were the single-channel and multichannel communications systems used in the Army's nuclear request/release and area communications networks. Hardening fixes for systems found to be vulnerable are currently in progress or have been completed.

Research continues to improve analytic and testing capabilities and to investigate the survivability of additional generic classes of tactical equipment. Future assessments will be directed toward air-defense systems, surveillance and target-acquisition systems, and computer-based systems.

TACFIRE. Assessment of the Tactical Fire Direction (TACFIRE) system has continued during FY79, focusing on several selected critical interface circuits. Detailed coupling analysis (supported and verified by tests) was completed, and the response of the critical circuits was determined. In addition, HDL examined and tested the EMP protection hardware, consisting of the cable shielding and field-wire filters, that was implemented in the system design. The results were presented at the 1979 DNA Symposium on EMP Hardening.[1]

Multichannel Communication Systems. Multichannel systems hardening is well into the production phase of the field-wire terminal protection devices (TPD's). First Article tests for an EMP product improvement program (PIP) are scheduled for early in FY80. Earliest deployment of these TPD's will be in FY80.

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[1]R. Gray, T. Mak, R. Reyzer, and M. Vrabel, EMP Hardening Pitfalls between System Design and Production, DNA Symposium on System EMP Hardening, San Diego, CA (7 to 9 August 1979).

Initial assessment of the HEMP hardening approaches for selected high-capacity multichannel communications systems was conducted to insure that the final hardening design approaches are compatible with the planned introduction of the new Digital Group Multiplexer family and the Short-Range Wideband Radio (SRWBR).

HEMP tests using the Army EMP Simulator Operation (AESOP) and current-injection techniques were conducted on the AN/TRC-122 troposcatter multichannel radio terminal, and results were reported to the Communications Research and Development Command (CORADCOM) and Pershing PMO.

Siliconized AN/VRC-12 Radio. The AN/VRC-12 radio is the basic communication workhorse for Army tactical operations. It had been previously assessed for HEMP transient damage. It has also been the subject of a recent PIP which considered the design for replacing many vacuum-tube and germanium transistor circuits with silicon transistor circuits. Because transistors tend to be more susceptible than vacuum tubes to damage from HEMP-induced transients, the PIP design required a new HEMP vulnerability assessment. The assessment used input transients calculated by the TWOWRE code, transients to the critical components calculated by the NET-2 computer code, and damage thresholds of critical components measured in the laboratory.

XM-1 Tank. In November 1978 an XM-1 tank was brought to the HDL Woodbridge Research Facility (WRF) for one month of EMP testing under the DT-II (developmental test) Integrated Test Program. The purpose of this project was to determine the susceptibility and survivability of the full-scale engineering development (FSED) model of the XM-1 tank to an exoatmospheric EMP environment. Testing was performed as scheduled using the Repetitive Electromagnetic Simulator (REPS), AESOP, and the Vertical EMP Simulator (VEMPS) test facilities, as well as current injection on selected cables.

Post-test activities have concentrated on test data analysis and bench stressing of selected XM-1 circuits. A full report will be published.

Patriot. The Patriot Project Manager's Office has tasked HDL to support the Test and Evaluation Command in preparation for HEMP qualification testing of a Patriot air-defense system fire unit. This fire unit consists of a shelter-housed engagement control station and radar set and a 150-kW electric power plant, all of which compose the fire-control section and associated launchers containing guided missiles.

Fire Unit. The testing plan for the Patriot fire unit consists of exposing the system to the AESOP environment and monitoring the critical system functions using built-in test equipment. The prequalification tasks conducted during 1979 included the following.

- A comprehensive scale-modeling effort in which the effects of HEMP angle of incidence, azimuth angle, and polarization were investigated in terms of identifying system orientations which correspond to worst-case configurations from an EMP coupling viewpoint.
- HEMP coupling and current-injection testing of the Data Link Terminal (DLT) antenna and transient protective circuitry (the DLT forms the communications link between the fire-control section and the launchers).
- Investigations into the use of system-built-in tests for detecting transient upsets within the system.
- Test plan preparations in which monitor points were identified and system hardware requirements were specified (certain hardware is to be adapted to allow for installation of transient monitoring apparatus).

150-kW Generator Set. A new electric power plant (EPP) is being considered for the Patriot fire-control unit. This candidate EPP, consisting of two 150-kW turbine engine generator sets on a truck, is being developed to replace the original four 60-kW diesel engine generator sets on a truck. The new control circuits for the turbine use integrated circuits.

A single 150-kW generator set on a truck was exposed to simulated HEMP transients under REPS and VEMPS. Cable-driving experiments were also conducted. The vulnerability was determined by scaling the measured transients to threat and analyzing the impact of these transients on the control circuits. A unique facet of the experiments was the effort to determine the source of the transients, whether from coupling through the housing or coupling through the finite shielding of the field cables. The analysis allowed allocations to be made for the amount of shielding required for the housing.

Defense Communication System Survivability. DCA has tasked HDL to develop a handbook of HEMP design practices which will be used to enhance the survivability of the future Defense Communication System (DCS). These practices are based on the results of previous system assessment and hardening projects performed by HDL. As part of this activity, HDL has developed plans for verifying the adequacy of key design practices, has formulated a set of HEMP specifications based on test data, and has reviewed military standards and specifications for HEMP hardening application and compatibility. Two system areas remain active from FY78. HDL is continuing its consulting role with DCA and the Military Departments (MIL DEP's) as an outgrowth of FY78's Satellite Terminal Program, and the surveys of and hardening recommendations for the AUTODIN II initiated under the Future Data Network program have continued.

DCA Handbook and Standards Support Program. The development of a HEMP Design Practice Handbook has continued through FY79, and a preliminary report has been given to the sponsor for review. Other related activities have included the development of test plans for evaluating and verifying the adequacy of high-priority design practices, the development of equipment HEMP specifications, and the continued support of the Defense Communications Engineering Center (DCEC) in a technical consulting role.

Design Practice Verification Plan. A test plan was written to initially identify a set of HEMP design practices requiring verification. The specific areas addressed were those which are widely applicable to the DCS and are important in providing HEMP protection, but for which little quantitative data exist. An integrated plan of test activities was generated, as well as several complementary approaches using analytics, bench tests, scale-modeling tests, and full-scale tests. Also addressed were aspects of data management, equipment, and test facility resources.

HEMP Specifications for Equipment. HDL has provided DCEC with a set of input specifications for protecting equipment against HEMP-induced electrical transient waveforms. The specifications were developed from scaled simulator test data on communication facilities. The test data base consisted of the SAFCA and PREMPT response data bases on AUTOVON communication facilities.

DCA HEMP Effects Consultation. HDL has continued its participation in the communication standards working group on grounding, bonding, and shielding. HDL has provided DCEC with a HEMP review of a number of military standards and specifications. Two reports have been generated for the National Communications System (NCS) under DCEC tasking. The first summarized the vulnerability of the DCS, and the second provided short-term and long-term guidance for minimizing this vulnerability.

Satellite Terminal Program. The study of HEMP effects on the Defense Satellite Communications System (DSCS) concentrated on the large, fixed-site AN/FSC-78 heavy terminal (HT) and AN/USC-28 spread-spectrum modem. Action by DCA has been taken to fund the implementation of the HDL recommendations to retrofit the existing HT sites. While this work was being completed, DCA obtained HDL assistance in applying design practices to mitigate HEMP effects in new satellite control facilities (network control element and real-time adaptive control). Through participation in design review meetings with other cognizant agencies, facility designs were modified to enhance HEMP survivability.

The MIL DEP's have requested assistance from HDL in providing HEMP protection for various communications facilities associated with satellite terminals. The US Army Communications Electronics Engineering Installation Agency (CEEIA) has begun a program with HDL to modify existing facility design criteria for the AN/GSC-39 medium terminal both in a van and in a fixed configuration. In addition, an effort for CEEIA has begun to provide a generic trade-off study of HEMP protection for interconnect communication facilities to be installed at US Army facilities throughout the world.

HDL participated in a power and grounding working group to resolve operational problems at one of the Air Force satellite ground stations. Although each participating agency expressed differing concerns, some of the HDL recommendations to improve HEMP survivability also improved proper terminal operations.

AUTODIN II. Four proposed AUTODIN II sites have been surveyed for good HEMP hardening design or practice violations. The results are documented in a very detailed survey report for the Andrews, Tinker, Albany, and Hancock AUTODIN sites.

Project APACHE. HDL continued to support the Defense Nuclear Agency on Project APACHE (Assessment of Pacific Communications for Hardening to EMP) by providing on-site technical guidance for the entire test program. An extensive vulnerability assessment for hardening to EMP was made on the Naval Communications Area Master Station, Eastern Pacific (NAVCAMS EASTPAC) at Wahiawa, Oahu, HI. Project APACHE, a joint project of DNA and the Commander-in-Chief, Pacific (CINCPAC), had as its verification phase the test at NAVCAMS EASTPAC. This test site was selected for its complexity and close juxtaposition of a large variety of comunications equipment. The TEMPS (Transportable EMP Simulator) was used in the test program to measure the accuracy of predictive techniques that have been used in assessing vulnerabilities of facilities throughout the Pacific Command (PACOM). The test program objectives were to

- confirm pretest prediction of facility response to simulated HEMP and to establish the confidence with which analytical HEMP predictions can be applied to the assessment of other PACOM C^4 (command, control, communication, and computers) assets,

- evaluate a number of assessment techniques employing varying degrees of low-level testing to support predictions that will help provide guidance for future vulnerability assessment and hardening programs, and

- verify the effectiveness of recommended hardness improvements.

This complex test program was completed and reported on in FY79.

HDL performed detailed analysis of the data taken during the test. The test responses were recorded on oscillograms and these were then microfilmed, hand-digitized, and recorded on an HP2116C minicomputer. The digitized data were analyzed on HDL's IBM 370/168 computer to determine the frequency response, so that a quantitative assessment could be made of high-altitude burst EMP coupling and equipment damage.

Assessment and Hardening for TRE. One objective of the program of transient-radiation effects (TRE) vulnerability and hardening is to evaluate the vulnerability of critical Army electronic equipment to the initial radiation, neutrons, and gamma rays of the tactical nuclear threat. In support of this objective, methods are developed, supporting documentation is drafted, and the TRE on piece-parts, circuits, and systems are determined. The evaluation of system nuclear response draws on semiconductor manufacturers' piece-part performance data, circuit design parameters, the Component Response Information Center (CRIC) data bank, and analysis methodologies which have been developed. Where necessary, the data are supplemented by piece-part or circuit testing in appropriate simulation facilities. The system response information is presented in a form most useful for Program/Project/Product Managers, in war gaming, and by

the Army tactics and doctrine community. In addition, hardening measures are recommended to the developing or managing agency wherever vulnerabilities are uncovered.

Single-Channel and Multichannel Communications. Assessment of tactical communication systems has been completed on the AN/GRC-142 single-channel and related radio teletypewriter systems, AN/TRC-145 and related low-capacity communications systems, AN/GRC-143 radio sets, the AN/GRC-165 radio set, the AN/GRC-177 radio set, the CV-425 telegraph-telephone signal converter, the TH-22TG telegraph terminal, and the KW-7, KY-57/58, and KY-38 tactical cryptographic systems. Reports have been published on the AN/GRC-142, AN/TRC-145, AN/GRC-165, AN/GRC-177, and KY-57/58. Reports on the other assessed systems are in press. A contract has been awarded for the assessment of six mobile electric power units.

Target-Acquisition Radar. Assessments have been completed on the AN/MPQ-4A and AN/PPS-5 radar sets. Some subsystems of the AN/MPQ-49 radar set have been analyzed, but the assessment of the total system is not yet completed. A contract has been awarded for the assessment of the AN/VPS-2 and AN/TPS-58 radars.

Command and Control Systems. Negotiations are under way for the assessment of the AN/GSG-10 (TACFIRE) and AN/TSQ-73 (Missile Minder) equipment.

Electro-Optic Systems and Components. The susceptibility and survivability of electro-optic systems and components in hostile radiation environments are being investigated. The systems under consideration are fiber-optic communication systems, image intensifiers, thermal imagers, laser designators and rangefinders, and seekers.

The losses induced in doped-silica fiber-optic waveguides from nuclear radiation depend on temperature, dose, and dose rate. Phosphorus was found to suppress the temperature dependence of the transient losses in Ge-doped silica fibers. The low temperature losses that are observed in GeO_2-B_2O_3-SiO_2 fibers during ^{60}Co irradiation are reduced in GeO_2-SiO_2 fibers containing no boron, and GeO_2-B_2O_3-SiO_2 fibers with high OH concentration show a reduced radiation response as the ^{60}Co dose rate is decreased. Neutron irradiation with a fission product spectrum was found to produce damage in GeO_2-B_2O_3-SiO_2 fibers corresponding to the neutron ionizing dose. These results show that the choice of a fiber cable for use in a particular radiation environment depends strongly on the temperature, dose rate, and performance requirements.

For example, for systems required to operate over a wide temperature range (–50 to 75°C) soon after a high dose-rate initial radiation environment, phosphorus-doped GeO_2-SiO_2 fibers represent the best choice of fiber composition. GeO_2-SiO_2 fibers containing no boron could be useful in initial radiation environments where the radiation is delivered in about 10 s and where low-temperature operation is required.

Serious nuclear thermal radiation effects were found in polyurethane-jacketed fiber-optic cables at fluences as low as 30 cal/cm^2, and no commercially available cables were found which were unaffected at or above 80 cal/cm^2. The exposure produced a significant reduction in the mechanical strength of the cables, making them very susceptible to catastrophic damage from the shock wave which would closely follow a nuclear thermal pulse. The threshold for damage was raised dramatically by the addition of aluminum foil and white Teflon tape layers under clear Teflon jackets. With this hardening technique, cables have survived 180 cal/cm^2. Figure 1 shows hardened and unhardened fiber-optic cables. A patent disclosure has been made for this hardening technique.

Hardened Tactical Shelter (HATS) Program. This project will develop a family of shelters addressing the NWE, NBC (nuclear fallout, biological, and chemical effects), and conventional fragment threats on the tactical battlefield. It will provide a survivable replacement for the current S-280 and S-250 electronic equipment shelters, and is being designed for use in developmental electronics,

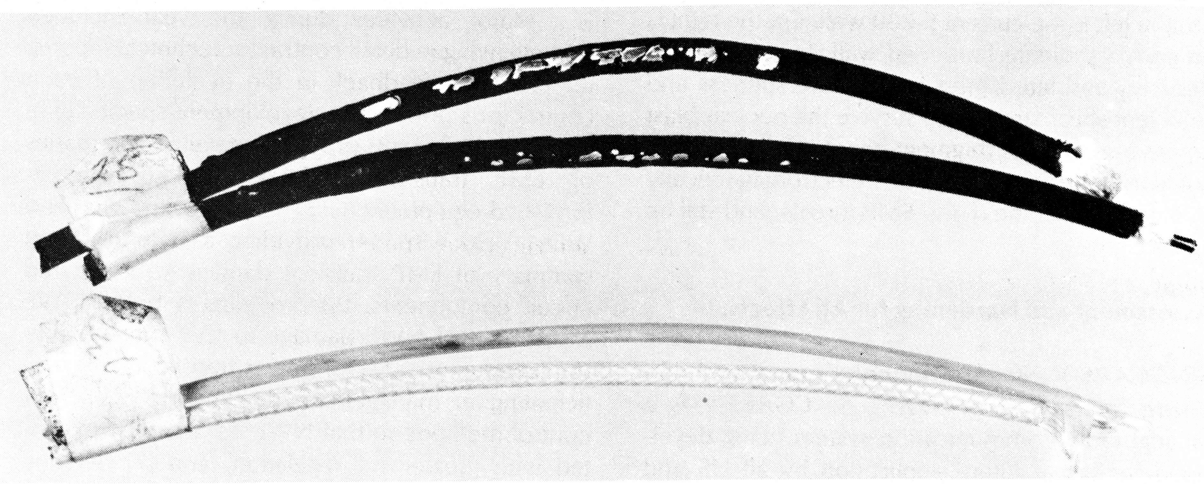

Figure 1. Comparison of unhardened (upper) and hardened (lower) fiber-optic cables.

communications, command, and control systems, as well as in surveillance and target-acquisition systems. It will also provide a replacement for fielded systems requiring survivability on the battlefield during the 1980's and 1990's. The Hardened Tactical Shelter is being developed under an accelerated schedule, beginning production at the start of FY83. Full production will transfer to CERCOM. The International Standards Organization (ISO) shelter program at Natick R&D Command (NARADCOM) will apply the HATS technology to its basic programs on the 8 by 8 by 20 ft ISO shelter and expandable semihardened ISO shelter, beginning in FY82.

The accelerated development program will have only one development phase; however, a unique management concept, "complementary technical paths," is being employed to assure program success. Under this concept, the hardening technology developed within the HDL and Ballistics Research Laboratory (BRL) 6.2 research programs will compete with the best of the industry candidates. The HDL/BRL design is designated as the model "T" and that of the industry candidates is model "O." Both shelters will compete in the development and operational test and evaluation phase.

The research program leading to the HATS project was managed under the HDL AH25 program, Nuclear Weapons Effects Research and Testing (NWER/T), and was accomplished at BRL with assistance from ERADCOM's Electronics Technology and Devices Laboratory (ETDL) and the Army Materiel Systems Analysis Activity (AMSAA). Test and analysis techniques were developed or improved; new materials, such as Kevlar, were explored for their use in fragment and thermal radiation protection; and state-of-the-art engineering practice was investigated for composite walls and bonding.

A wide range of shelter wall-panel constructions are under consideration in the model "T" program phase. Figure 2 demonstrates the differences in design required under the HATS project.

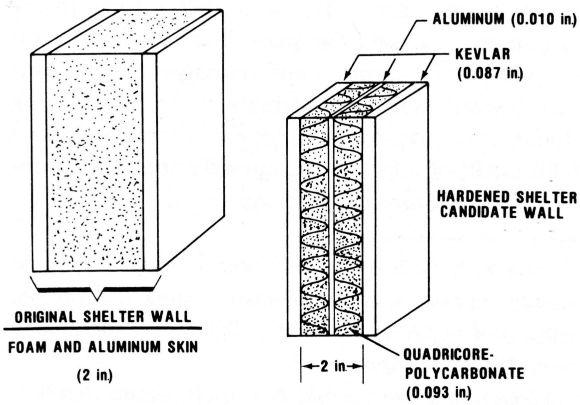

Figure 2. Comparison of original and candidate hardened shelter walls.

On the left is the current S-280 wall. On the right is an early candidate hardened wall design. All wall designs considered must incorporate stiffness and sufficient shear strength to survive the nuclear blast environment, resist fragment penetration, resist the nuclear thermal pulse, be electromagnetically shielded against the rf and EMP threats, and still be lightweight.

Assessment and Hardening for All Effects.

SINCGARS-V (Single-Channel Ground and Airborne Radio System—VHF). SINCGARS-V is a tactical radio communication system being developed for broad future application by all US and NATO services. It will be used by ground troops, on land vehicles, and on helicopters. It will have capabilities for clear voice, secure voice, data, and electronic counter-countermeasures (ECCM) by frequency hopping. The three contractors developing the system are Rockwell-Collings, ITT, and Cincinnati Electronics Co./Mullard. HDL has been funded by DNA to help the Program Manager assure that the contractors are responding to the NWE requirements of their contracts in a positive and cost-effective manner. The greater purpose of the DNA-funded effort is to provide detailed guidance and an example for Program Managers to follow in implementing NWE requirements in future system procurements.

Blast, thermal radiation, TRE, and EMP survivability are all being addressed under this program by a team from HDL and BRL. Two major documents[2,3] have been published which describe the technical approach and management philosophy toward NWE survivability. Other supporting documentation provided specific information to the SINCGARS-V contractors. Surveillance of the contractors' programs is continuing.

Major activities during the year included (1) reviewing in detail contractor technical reports, (2) providing feedback in the evolution of each contractor's prime item development specification and design plan, (3) providing detailed summaries of EMP transients induced by government-furnished-equipment (GFE) helicopter antennas and WD-1 field wire, (4) providing a state-of-the-art summary of EMP transient damage to integrated circuit components, (5) providing a broad NWE assessment of NWE damage to "V" metal-oxide-semiconductor (VMOS) power transistors, (6) participating in management meetings to work out control methods so that NWE tasks can be executed with greater self-regulation, and (7) deriving acceptable integration test requirements as the end items are being built up.

Individual circuits are currently being designed by the contractors, with breadboard operation scheduled for next year. Because of the general lack of appreciation of the requirements for NWE hardening in industry, HDL has had to constantly strive to keep NWE from being neglected or waived. A format for monthly reports has been derived to force the contractors to focus on critical areas in the NWE facets of their design.

Nuclear Effects Support Team. The Nuclear Effects Support Team (NEST) was formed to provide expertise in NWE to developers of Army materiel that needs nuclear survivability features. The team consists of experts in all areas of NWE, including blast, thermal radiation, initial radiation, and nuclear EMP. A major goal of the NEST is to transfer the latest NWE technology from the laboratory to the materiel developer. The team has provided various Army development projects with (1) blast and thermal data on helicopters, (2) initial radiation data on electronic piece-parts, (3) blast data on communication/electronics shelters, and (4) guidelines on addressing the nuclear survivability of devices that use the latest semiconductor technologies.

During FY79, NEST has assisted materiel developers in the formulation of Requests for Proposals (RFP's); reviewed Nuclear Vulnerability Study

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[2] *J. Halpin, J. Swirczynski, G. Teele, E. Quigley, and M. Campi, Nuclear Weapon Effects on Army Tactical Systems, Vol I—Overview, Harry Diamond Laboratories, HDL-TR-1881-I (April 1979).*

[3] *J. Halpin and J. Swirczynski, Nuclear Weapons Effects on Army Tactical Systems, Vol II—Management, Harry Diamond Laboratories, HDL-TR-1881-II (May 1979).*

Plans, Hardening Design Guidelines, and Engineering Change Proposals (ECP's); written Statements of Work (SOW's); witnessed nuclear tests performed by the contractor; served as members of Source Selection Evaluation Boards (SSEB's); and participated in Design Reviews (DR's), Systems Requirement Reviews (SSR's) and Test Integration Working Groups (TIWG's).

NEST provides assistance to projects in all the DARCOM R&D Commands. Among the 26 materiel development projects receiving NEST support in one or more areas discussed above were the following.

Firefinder
Remotely Piloted Vehicle (RPV)
Advanced Attack Helicopter (AAH)
Position Location Reporting System (PLRS)
Division Air Defense Gun System (DIVADS)
Fighting Vehicle System (FVS)
Tri-Service Tactical Communications Agency (TRI-TAC)
Modular Integrated Communications Network System (MICNS)
Standoff Target Acquisition System (SOTAS)
Tactical Operations System (TOS)
General Support Rocket Testing (GSRS)
Satellite Communications Agency (SATCOMA)
Global Positioning System (GPS)

Nuclear Weapons Effects Technology Development/Application

A key element in the NWE program is the development of the tools and technology to perform the vulnerability assessments and hardening of systems. Equally important is the determination of the NWE sensitivity of new attractive system design and fabrication techniques to assure that nuclear Achilles' heels are not inadvertently built into systems in the pursuit of cost-effectiveness. In addition, every effort is made to apply or transfer gains achieved in weapons effects to other areas.

EMP Technology Development.

EMP Environment Research. The general objective of EMP environment research is (1) to define the EMP environments associated with realistic tactical burst conditions and, subsequently, (2) to develop EMP environment criteria for assessing system vulnerability to tactical threats. Accurate temporal and spatial descriptions of the EMP, its source currents, and the associated time-varying air conductivity for near-surface/low-altitude nuclear bursts are required to establish EMP environment criteria.

The NEMP computer-code system for predicting EMP environments of tactical near-surface airbursts has been completed and has been used to predict the EMP environments of a growing number of US stockpile weapons. These EMP environment predictions will be developed into an Army Tactical Burst EMP Library for use in assessing system vulnerability and in developing future EMP survivability criteria. The NEMP predictions represent the pinnacle of the state of the art for describing EMP environments of near-surface airbursts.

NEMP EMP predictions were made for a number of bursts at the Nevada Test Site during Operation Plumbbob in 1957. During this test series HDL scientists measured EMP magnetic fields produced by the bursts. The NEMP predictions compare very well with the measured data, giving strong support to the credibility of the NEMP prediction scheme.

EMP Coupling Analysis. The EMP vulnerability of military systems is primarily due to the EMP response of deliberate antennas, such as communications antennas, and of nondeliberate antennas, such as cables and transmission lines. Many types and configurations of antennas and cables are used in military systems, and the EMP response of such cables and antennas must be determined before a damage assessment can be made. In order to facilitate the damage analysis, the antenna or cable is represented in terms of either a Thevenin or Norton equivalent circuit for which the source term is a function of the incident EMP. The various parameters required to describe the equivalent circuit are

determined by the use of the computer codes TEMPO (for antennas), FREFLD (for shielded cables), and NLINE (for multiconductor transmission lines).

A code, SCWAR,[4,5] has been developed which uses the output of FREFLD to calculate the distribution of coupled current on the internal conductors of a shielded, multiconductor cable. Another code, MCABLES,[6] is a variation of FREFLD that can treat the situation where several cables of different lengths meet at a single node. Finally, a third code was developed to determine the coupled response of field wire terminating in an unbalanced load.[7]

The theoretical computations for the interaction and coupling codes are supported by experiment as much as possible. For example, antenna computations have either been verified at the HDL cw test facility or, for complex antenna systems, data from the cw facility are used directly as part of the analysis. For cables and transmission lines, some of the parameters required to determine EMP response and an equivalent circuit are found experimentally with an automated network analysis system. Unusual or highly complex models of cable-coupling problems are typically validated with representative tests conducted with one of the Army's EMP simulators at the Woodbridge Research Facility. Only after sufficient verification will a coupling model be applied in a system's vulnerability assessment.

During FY79, HDL conducted a detailed coupling analysis and a subsequent test of selected subsystems of the TACFIRE system. Comparison of the predicted system response and measured signals resulting from exposure to simulator environments indicated that the coupling models that were developed to assess the vulnerability of the system are correct.

The circuit-analysis code NET-2 has been fully adapted for use in assessing the selected TACFIRE circuits. The program, maintained on the HDL IBM 370/168 computer, can be readily accessed from WRF, and circuit analysis (once the circuit model is generated) can be routinely performed.

EMP Hardening Technology. For communications equipment, one of the major penetration points for EMP is the radio antenna. Hardening applied at the antenna is particularly efficient, but generally must be tailored to the characteristics of the antenna. Thus, a major effort has been devoted to the evaluation of six antennas used with single-channel net radios. EMP signature, typical radiation and reception characteristics, and the effects of terminal protection devices (TPD's) are some of the data of interest.

The coaxial voltage clamp (CVC) is a TPD applied to the antenna input of a single-channel net radio. Extensive reception and transmission tests have been completed which assess the voltage standing wave ratio (VSWR) and other insertion parameters, as well as transmission range with the CVC deployed. Preliminary results show that a radio with a CVC installed will remain within its original Depot Maintenance specification.

A shelter test facility conceived in FY79 has been partly constructed and will be complete in early FY80. The facility consists of S-250 and S-280 shelters with appropriate wiring and entry panels, etc, but no equipment in the racks. Thus, valuable communications gear will not be tied up in a facility where most data are taken at interfaces external to the equipment. When appropriate, certain modules can readily be installed for specific tests.

A wide variety of EMP pulse waveforms can be generated in the shelter facility, including lightning-like pulses of very high energy (15 kJ). A

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[4]*M. Vrabel, The Multiwire Shielded Array—Theory and Code, Harry Diamond Laboratories, HDL-TR-1873 (October 1978).*

[5]*M. Vrabel, User's Manual for SCWAR—A Multiwire Shielded Cable Code for a Systems Oriented EMP Vulnerability Assessment Program, Harry Diamond Laboratories, HDL-TR-1887 (May 1979).*

[6]*R. Gray, EMP Response of Field Wire Terminated in an Unbalanced Load, to be published.*

[7]*R. Gray, Program MCABLES, to be published.*

special differential instrumentation system has been designed for the shelter test facility, and fiber-optic data transmission will also be available. With this facility on-line early in FY80, HDL will be capable of a rapid turn-around for critical system data that used to be subject to shelter-availability delays of up to months.

Terminal Protection Devices. Major emphasis on TPD's has been in the area of *in situ* performance. Tests of multichannel TPD's and single-channel coaxial devices (CVC's, for example) have resulted in a realistic assessment of what happens in actual protected systems with EMP threatening.

Private industry sources have been informally appraised for potential producibility studies of coaxial spark gaps (CSG's) and protective binding posts (PBP's).

Integrated Transitional Hardware (INTRAD). Packaging of TPD's is an area of hardening with the least freedom of design. The importance of hardware packaging is usually concealed by circuit development and component selection.

The INTRAD program is a composite of these areas and thus provides a transition between circuit development to hardware and the integration of this hardware with communication systems as retrofit/prototype fixtures.

INTRAD's are designed to meet system size, weight, interfacing, serviceability, and environmental specifications. Examples of INTRAD's include CSG's, CVC's, and PBP's.

Evaluation of Component Degradation for EMP Vulnerability Assessments. Continued progress has been made in the computer study directed toward understanding the basic physical processes involved in the initiation of second breakdown. A comprehensive study has been made of the effect of various doping profiles upon the reverse-bias second breakdown of silicon diodes. Two-sided abrupt junction diodes were computed to be least susceptible to second breakdown, followed in order by linearly graded junctions, p-type devices, and, most susceptible, the most common device, the n-doped diode.

Studies have also been made of forward biased diodes at very high powers. Although fields high enough to initiate ionization were calculated, no negative resistance resulted. It is the negative resistance of reverse-biased diodes which causes current constriction and damage. Using steady-state conditions for forward bias as initial conditions, reverse switching into avalanche was calculated. The stored charge is shown to affect the breakdown transition.

Device Damage Testing. Device damage testing in support of systems analyses within MSEP consisted of step-stressing semiconductor devices with square pulses of voltage to determine (1) the pulse power for failure or second breakdown as a function of pulse width and (2) the device impedance for pulse amplitudes up to the failure level. This information, needed for computerized circuit failure analysis, was provided for several types of discrete diodes and transistors and for several types of linear and digital microcircuits of TACFIRE.

Device Damage Response Variability. A study of "intervendor variations" in the pulse hardness of discrete semiconductor devices showed that the average pulse power for failure of a given type (e.g., 2X4237) can vary by more than three orders of magnitude between samples from different manufacturers. These variations are due to different designs or manufacturing processes of a device type which vendors are free to select. In support of systems analyses, generally, devices from only one vendor are damage tested to determine their failure characteristics (see *Device Damage Testing,* above). This type of test must suffice because details of the design of a device type employed in the often numerous units of a fielded system are unobtainable. Further studies will be aimed at establishing the frequency of occurrence of large intervendor variations in discrete devices. If intervendor variations of the recently found magnitude are prevalent, the effect on systems analyses will be large uncertainties in the failure levels of devices. In fact, it may become necessary to assume the failure

levels of the most sensitive devices to apply to all device types of a certain class (e.g., to all low-power transistors).

Foreign Technology. A component damage study was undertaken by HDL to determine the susceptibility of foreign-made semiconductors to EMP-type transients. This effort consisted of selecting various devices by choosing parameters that would be similar to US counterparts.

Square-wave pulsing from 0.1 to 10 μs was performed on Siemens and Telefunken devices, which were also compared to US counterparts as to chip area and power rating. Several static induction transistors (SIT's) from Yamaha were also damage tested; however, no correlation studies were made to these devices, since this technology does not presently exist in the US.

Tactical Environment Multiple Systems Evaluation Program. The Tactical Environment Multiple Systems Evaluation Program (TEMSEP) is a joint Army/DNA-funded effort. The primary objectives of the program are to (1) develop analytical methods to assess the vulnerability of Army systems to tactical endoatmospheric nuclear threats, (2) develop a capability for experimentally verifying the analytical methods, thereby establishing confidence in them, and (3) apply the technology to assess the vulnerability of critical Army systems. During FY79 several significant advances were made toward meeting these objectives. Using the AURORA Flash X-Ray Facility, augmented with a large parallel-plate transmission line, HDL performed controlled diagnostic experiments which verified the analytical methods used to determine the endoatmospheric EMP response of monopole antennas.

Source-Region EMP Coupling and Simulation Research. In order to address the objectives of TEMSEP (previously discussed), several supporting research efforts were undertaken. It had been previously recognized that the AURORA Flash X-Ray Facility is a potent simulator of transient gamma radiation but, because of the structure of the facility and the temporal behavior of the radiation output, the resulting EMP environment in the exposure room differs significantly from that expected from an endoatmospheric nuclear detonation observed at the same conductivity levels. Relying extensively on theory and on previous environmental measurements in the "bare" exposure room, a large-pulsed parallel-plate transmission-line field generation structure was designed and erected at the AURORA facility. Using a fiber-optic data-transmission system and field sensor (hard to radiation) developed by HDL during early FY79, it was demonstrated that over a few meters, the important electromagnetic features associated with an endoatmospheric nuclear detonation could be produced. Then, using this experimental apparatus, several antenna structures and the AN/PRC-77 manpack radio were exposed, and the response was measured. These tests confirmed that several analytical methods used to calculate the response of monopole antennas to the endoatmospheric EMP environment can be used with confidence.

In a separate effort, HDL developed an approach to adapting current-injection methods for simulating the response of cables exposed to the endoatmospheric EMP environment. The approach, based on a lumped-parameter representation of the cable, reduces the number of elements from literally hundreds to less than ten. This has been analytically demonstrated this fiscal year and experiments to verify it are planned for next year.

SGEMP Technology Development. Under tactical nuclear warfare conditions, typical Army electronic shelters, such as the Army S-250 and S-280, may be expected to encounter radiation environments for which the gamma-radiation dose rate may reach levels of 10^9 rads(Si)/s. Experiments using the Aurora facility have confirmed predictions of internal system-generated EMP (SGEMP) fields that may be only 20 dB below the unshielded values of the associated EMP of the source region. The SGEMP fields, moreover, are characterized by a higher frequency distribution of energy than the EMP fields.

In the present program, predictions of Compton current air conductivity and E and H field time

histories inside an S-280 shelter have been made for several weapons of different yield at critical ranges. Fourier transforms of the fields were obtained for subsequent cable current coupling predictions. Time histories were then obtained for bulk cable currents induced by the fields using the SCEPTRE network code in the frequency domain. The peak currents calculated are more than sufficient to upset a computer-controlled system, as demonstrated by results of a recent current-injection study on a minicomputer. Burnout may even occur in low-level circuits of a system. Work is continuing in the development of approximate analytic formulas to calculate fields and cable coupling for Army systems and to experimentally verify these predictions.

TRE Technology Development.

Radiation Effects on Metal-Oxide-Semiconductor (MOS) Devices. A new electrical technique which does not depend on radiation sources was developed for evaluating the hardness to ionizing radiation of MOS gate insulators. The gate insulator under test is subjected to positive high-voltage pulses which cause electrons to be injected into the gate oxide via Fowler-Nordheim tunneling from the Si substrate. A fraction of the injected electrons then create electron-hole pairs in the bulk of the oxide by impact ionization. The resulting electrons and holes behave similarly to electrons and holes generated by radiation sources (e.g., ^{60}Co, x ray, LINAC). The electrons are swept out while the holes drift to the Si interface where they may become trapped, cause interface state production, or be removed. Thus, the technique simulates nuclear irradiation of the gate insulator. A variety of both radiation-hard and -soft gate oxide samples obtained from various vendors were tested by the high-voltage technique, and their responses under the test were compared with the responses of similar samples to ^{60}Co ionizing radiation. The flatband voltage shifts induced by the high-voltage pulse test and the ^{60}Co irradiations were found to be well correlated (see fig. 3); that is, the test was quantitatively sensitive to the radiation susceptibility of the various samples. The high-voltage test also produced changes in interface state densities and

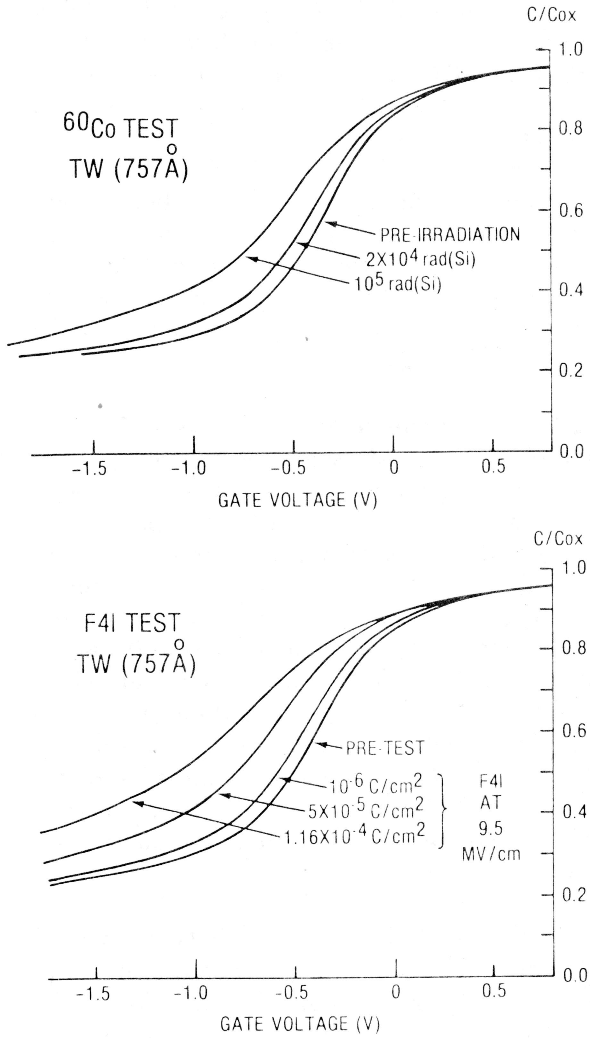

Figure 3. Comparison of MOS capacitor response to F41 test and ^{60}Co irradiation.

laterally nonuniform charge densities that were similar to those produced by ^{60}Co irradiation. The high-voltage pulse test therefore shows promise as a tool for sampling or screening for the total ionizing-dose radiation response of MOS devices.

Power VMOS. Radiation damage studies on VMOS power devices were carried out by HDL to assist in meeting the nuclear hardening requirements for the SINCGARS program.

This new technology represents the first effort to obtain MOS power at rf. Since VMOS devices

have two major advantages over counterpart bipolars, a low-noise floor level and higher efficiency, the SINCGARS contractors are seriously considering the use of VMOS devices for the output and driver transmitter stages.

Ionizing and nonionizing radiation studies were carried out on this new technology to determine the susceptibility to neutrons, gammas, gamma dot, and EMP-type transients. These data were presented at the November MIDCOM/79 conference in Chicago.

Radiation Vulnerability of Large-Scale Integrated Circuits. Measurement techniques have been developed to investigate LSI devices for total dose, dose-rate-induced upset, latch-up, and permanent failure. Commercial microprocessors, random access memories (RAM's), and input/output devices are the main focus of this study. Instrumentation has been developed to measure 1802, 6800, 8080, 8085, and 9080 microprocessors and a host of static RAM devices. Device performance can be measured "under power," during irradiation. Irradiation experiments are being performed at HDL's high-intensity flash x-ray (HIFX), the HDL cobalt-60 source, and the Naval Research Laboratory (NRL) linear accelerator (LINAC).

The microprocessor instrumentation that has been developed compares two microprocessor systems performing identical instruction lists while driven from a single clock. Comparison is performed on the address and data lines to determine device-under-test performance. Both systems are commanded remotely to execute the instruction list. Single address or data-line bit failure can be determined and recorded. This system has been employed to measure all five types of microprocessors mentioned above. Device failure levels have been established for ^{60}Co source irradiations and can be ranked from more radiation resistant to less resistant—1802, 9080, 8085, 6800, and 8080. The 9080 microprocessor is electrically equivalent to the 8080, but is six times more radiation resistant. These results significantly affect some Army development programs, since the 9080 and 8080 are typically specified as being interchangeable. Similarily, 8080 microprocessors from different vendors have been found to respond differently. We are investigating ways to avoid unfavorable interchange of devices. Dose-rate experiments have been performed using the HIFX and LINAC sources. Permanent dose-rate effects and latch-up characteristics have been measured. The 1802 device exhibits latch-up problems at dose rates less than 109 rads(Si)/s. No other microprocessor tested exhibited latch-up characteristics, but permanent damage levels have been established for each type. None of the devices measured had dose-rate failures $< 10^{10}$ rads(Si)/s.

Component Hardness Assurance. HDL is managing the neutron hardness assurance program for DNA. A guideline document has been written and is being circulated for review by the technical community. Intended to be used by design engineers, this document provides a systematic approach to guarantee system survival at some specified probability and neutron threat level. It includes all control, monitoring, and evaluation efforts needed for the piece-parts. The document gives guidance on such things as how to choose devices, which parameters to control, how to acquire and use small-sample data, and how to apply hardness assurance at the supplier level as well as at the user level.

NWE Applications.

Fiber-Optic Instrumentation Development. A first model of a high-accuracy radiation-resistant fiber-optic signal link has been developed for use with the Satellite X-Ray Test Facility (SXTF). The design of this new system is based on the original radiation-hardened optical link developed for use with the OWL-II exploding-wire simulator in 1976 to 1977. The link consists of an optical transmitter (inside the object being irradiated), an interconnecting fiber-optic cable, and an optical receiver which is connected to the recording and analysis equipment. For use with SXTF, the optical transmitter must be physically much smaller and lighter than that used with OWL, as well as more radiation resistant. To accomplish this, major changes in the optical fiber and laser transmitter were necessary.

Since most of the published data on the radiation response of optical fibers does not include the instant of irradiation, but instead lists fiber response only microseconds or more after irradiation, it was necessary to design and conduct experiments in our facilities to obtain the nanosecond-resolution fiber-response data needed for design of the SXTF system. A modulated double-heterojunction laser was used as an optical signal source to drive the optical fiber being tested, and a 500-MHz optical receiver (fig. 4) was used to detect the signal transmitted through the fiber. Fibers were exposed to levels between 20 and 2000 R from the HDL FX-45, and the darkening of measured fiber lengths was determined. A continuous record was obtained from before irradiation to milliseconds afterward. Optical filters allowed a separate evaluation of both darkening and luminescence (Cerenkov radiation). A commercially available graded-index fiber made by the internal vapor-deposition process was found to have the best properties for the SXTF application. New fibers are being evaluated as they become available.

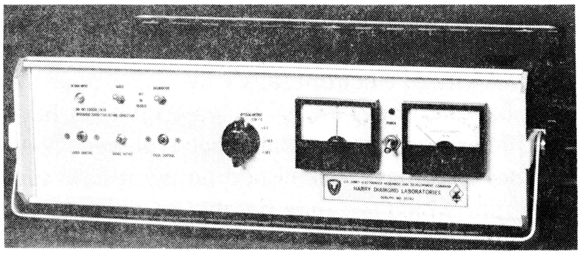

Figure 4. 500-MHz optical receiver.

In order to minimize battery current and maximize signal linearity, a single-mode laser was chosen for the SXTF optical transmitter. These lasers are much improved over the multimode lasers used in the original OWL-II links. The single-mode lasers, unfortunately, give rise to a new problem, recognized in 1978, called "modal noise." This noise, which can cause extreme signal interference, is a result of optical interference between the modes propagating in the optical fiber. The interference is increased by the spectral purity of the emission from single-mode lasers. A unique means of reducing this modal noise was developed for the SXTF optical link and a patent has been applied for.

Suppression of Modal Noise in Fiber-Optic Systems. We have developed—and previously reported—wideband analog fiber-optic links for use in acquiring data from EMP and SGEMP test objects where dielectric isolation of the test object is required. Such isolation is often necessary in the simulation of NWE, because metallic signal-carrying cables would either perturb the measurement or pick up interfering signals. In order to achieve the desired 500-MHz baseband transmission, the transmitter must use a cw injection laser diode rather than a light-emitting diode. Recent advances in fabrication technology have yielded laser diodes featuring much improved confinement of the lasing action and, in consequence, exceptional linearity. However, such sources are also highly monochromatic, so that optical interference effects, previously unobserved, become inevitable.

In particular, small wavelength shifts or mode hops, randomly engendered within the laser or in response to the modulating signal or to temperature changes, alter the distribution and amplitude of the modes propagating in the fiber to which the laser is coupled. The properties of the fiber and the inter-fiber connections are such that all modes do not propagate with equal loss and exactly equal delay. Because of this, a varying speckle (interference) pattern forms at the surface of the receiving detector, resulting in considerable spurious noise. That is, the perfectly satisfactory output of the laser becomes distorted at the detector by the addition of this "modal noise." Recognizing that this was a modulation of the system gain rather than the additon of an independent noise source, we contrived a novel method of gain-averaging. A relatively large 2-GHz modulation is added to the existing laser bias and modulation. The speckle pattern at the detector is thus caused to vary at the 2-GHz rate, i.e., faster than the detector can respond to it. Therefore, the gain variations are largely averaged out, so the worst effects of the modal noise are suppressed.

Parametric Measurement of Microwave Output of the Reflex Triode. A considerable movement is under way within DoD to develop ultra-high-power microwave sources. Potential uses are weapons,

countermeasures, radar, systems vulnerability (RFI) testing, rf heating of plasmas, and electron acceleration. Previous microwave measurements of X-band output from a simple planar reflex triode showed a strong dependence of peak output power upon the externally applied axial magnetic field. The peak X-band power was measured to be approximately 1 GW on several shots for low applied magnetic fields (<1 kG); however, experimental time constraints prevented a detailed investigation of the phenomenon. This year, a detailed experimental study has been performed of microwave output power in X, Ku, and K bands as a function of the applied magnetic field.

The parametric study showed resonances in the output of the triode at low (<500 G) magnetic fields for all microwave bands (X, Ku, and K) covered by the diagnostics. The output power peaked in the X and Ku bands, with peak powers in both bands being 1 GW. The K-band output peaked at an applied field of 75 G with a peak power of 0.25 GW. In addition to the microwave diagnostics, these experiments used voltage, current, and diamagnetic field probes (fig. 5).

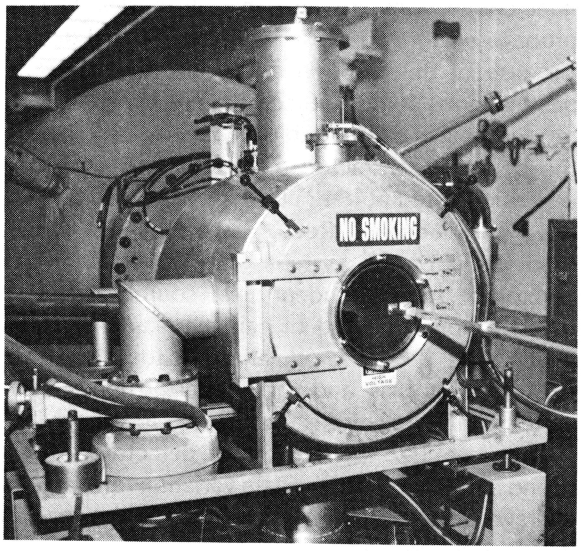

Figure 5. Reflex-triode experiment attached to FX-45 flash x-ray machine.

Stimulated Near-Millimeter Radiation due to Static Wiggled Magnetic Field. A very promising mechanism for efficiently (~10 percent) producing near-millimeter (NMM) waves has been investigated theoretically, based on an example taken from an ongoing university experimental effort.

The specific example of the wiggled magnetic field used in this analysis—stimulated electron radiation in the dielectric medium—was taken from the Dartmouth College Plasma Physics Group (John Walsh et al), where experiments to produce the NMM wave radiation are in progress. In this experiment, one allows an electron beam of about 100 keV to pass through a quartz tube of 1 cm in diameter in which the wiggled magnetic field with a "wavelength" of about 1 cm has peak values of 4 kG parallel and 1 kG perpendicular to the motion of electrons.

The power spectrum in this analysis was calculated from the "excitation" amplitude of a medium. The total radiated power was determined as an integral of the power spectrum over the frequencies of interest. Specifically, we have derived the explicit expression for the total radiated power, W_T, when the radiation occurs below the Cerenkov threshold, where n (the index of refraction) and v (the velocity of electron) satisfy $nv \lesssim 1$. Above the Cerenkov threshold ($nv > 1$), we do not yet have specific expressions for total radiated powers. Nevertheless, we have established an interesting sum rule from which we may be able to estimate W_T when we are slightly above the Cerenkov threshold, $nv \gtrsim 1$. The example of the wiggled magnetic field produced at Dartmouth College, given the assumptions above, implies that this is a very promising mechanism for efficiently producing NMM radiation.

NWE Simulation

Since at this time tests cannot be conducted in a real nuclear weapon environment, simulators are the only available link to reality. The goal of this element in the NWE program is to operate and develop the most realistic simulators for effects research and system testing.

EMP Simulators.

Army EMP Simulator Operation (AESOP). The AESOP was developed and erected through DARCOM sponsorship as a high-level EMP simulator, with its fixed site being the HDL Woodbridge Research Facility. AESOP can produce 50 kV/m, free-field, at 50 m on its centerline. AESOP has continued to support the Army and a variety of DoD customer test programs throughout FY79. This facility is available to DoD contractors and to other government agencies.

During FY79, AESOP supported such high-priority DoD EMP test programs as the XM-1 tank, the Patriot power module, TACFIRE, and the AN/TSC-85/93 satellite terminals.

Also during FY79, AESOP was upgraded by the installation of a high-voltage electronic trigger system, an on-board diagnostic system, and a custom-built handling fixture for transporting AESOP to and from the new High-Voltage Laboratory Facility.

Transportable Electromagnetic Pulse Simulator (TEMPS). The TEMPS threat-level EMP simulation facility was developed by HDL for DNA. Following the DNA APACHE test at the Naval Communications Center at Wahiawa, Oahu, HI, HDL provided DNA with extensive test-data reduction and analysis for a vulnerability assessment of the NAVCAMS EASTPAC communication complex during FY79.

Low-Level Simulators. HDL has a family of low-level simulators, consisting of (1) the Repetitive Electromagnetic Pulse Simulator (REPS), (2) a low-level Repetitive Pulse Generator (RPG) used in the AESOP antenna structure, (3) the Vertical Electromagnetic Pulse Simulator (VEMPS), and (4) a quarter-megavolt RPG. These simulators offer an economical approach to obtaining EMP signature data on various kinds of equipment. Their repetitive capabilities ensure maximum data gathering at minimum cost.

Repetitive Electromagnetic Pulse Simulator (REPS). Under the sponsorship of the Army Corps of Engineers, HDL developed a reliable self-contained transportable simulator suitable for supporting EMP field tests at the Stanley R. Michelson Safeguard Complex, Grand Forks, ND, and the Safeguard Missile Site Radar Power Plant, to determine the susceptibility of these facilities to EMP.

This megavolt repetitive simulator can provide an EMP free-field environment of 6 kV/m at 50 m on the pulser centerline. This system radiates a threat-related waveform with a rise time of less than 10 ns and pulse duration of approximately 800 ns. REPS is presently set up at HDL to support Army EMP test programs. This system is available as a permanent repetitive EMP test facility.

During FY79, REPS was used to support testing of the XM-1 tank, the Patriot power module, and TACFIRE.

Vertical Electromagnetic Pulse Simulator (VEMPS). VEMPS offers support to Army EMP test programs requiring a high-frequency, fast-rising EMP with a primary vertical field. VEMPS can radiate an electromagnetic free field up to 2 kV/m at 50 m from the antenna. The rise time of this simulator is less than 10 ns, and the pulse duration is approximately 100 ns.

Tests involving the above simulators have been considerably improved during FY79 by the upgrading of the instrumentation van with wide-band fiber-optic data links and a transient digitizing, recording, and data processing system for automatic analog-to-digital conversion of EMP data.

Continuous Wave Facility. The Continuous Wave (CW) Test Facility is an outdoor measurement system for determining the interaction and coupling characteristics of antenna systems in the presence of a finite conducting ground. It consists of a set of antennas that can radiate broad-band vertical or horizontal polarized fields over a 100- by 200-m test area and an automated data-acquisition system to measure the test antenna response relative to the incident field. The frequency range (2 to 500 MHz) of the transmit and receive systems spans the major portion of the EMP spectrum; hence, the facility is

used to study EMP-related interaction and coupling problems. This is accomplished by making the appropriate measurements required to represent the antenna system by a Thevenin or Norton equivalent circuit for a specified EMP. The data are recorded in digital form on cassette magnetic tapes and are then transferred via telephone lines to HLD's IBM 370/168 computer for subsequent data analysis.

Electromagnetic Scale-Modeling Facility. During FY79, the electromagnetic scale-modeling facility was used to perform coupling studies for the Patriot system and special projects. Programs were written for the minicomputer-controlled analog-to-digital processing to allow the azimuthal response of a test object to be plotted in polar form and to remove the frequency response of passive components, such as cables. An experimental electric field sensor was built and tested, and a 50:1 model of the AESOP facility was fabricated.

EMP Simulator Support Facility. Under the direction of the Corps of Engineers, a High-Voltage Engineering Laboratory and a separate Command and Control Center for AESOP were completed. The High-Voltage Engineering Laboratory provides the Army with extensive repair and maintenance capabilities on its large, high-voltage EMP simulators, and it provides a greater capability in the research and development of new EMP simulators. Complete simulator overhauling and maintenance activities can be performed in the high-bay area on this new controlled environment facility. Efficiency in simulator maintenance also was enhanced by the establishment of a new Calibration/Maintenance Laboratory.

The Command and Control Center provides AESOP with a single permanent enclosure for the complex pulser control console, along with facilities for performing minor maintenance on the pulser Marx generators, trigger system, and peaking capacitors.

Radiation Simulators.

AURORA. The rate of use of radiation simulators has been high, in both the bremsstrahlung and electron-beam modes, even though the Marx generator has been beset by an unusual series of problems. All the services were represented as users, with Trident, MX, Mark 12A, and the DNA/HDL source-region EMP measurements being the heaviest users in the bremsstrahlung mode. Also tested were the HDL M735 fuze/setter and several NSA secure communications systems. The Chair Heritage program and the HDL/DNA materials program were the primary users in the electron-beam mode. These tests used a new, high-intensity electron-beam capability that was designed and built during the year. This produces energy depositions of about 1500 cal/cm^2 over an area of a few square centimeters. This is a really remarkable beam intensity and will prove to be very useful in several applications. A digital data system has been installed, primarily to support the AURORA Modification Project. The system can digitize analog data presented in either electrical or photographic form; it will also be used to support AURORA users.

Over the past several years, much work has been done to extend the range of radiation output intensities available in the bremsstrahlung mode and to increase the reliability of the simulator. The results of this work have been consolidated in a report now in press. A separate report on capacitive voltage monitors for many megavolt applications is also in press.

High-Intensity Flash X-Ray (HIFX) Facility. The HIFX facility has been extensively used, primarily by Army projects. Most of the second quarter of the fiscal year was devoted to diagnosing and resolving a column discharge problem, which now appears to have been eliminated. This high use rate has provided funds to continue the instrumentation upgrading program made necessary by the rate at which our present instrumentation is galloping toward obsolescence and decay.

Cobalt-60 Source. The cobalt-60 facility has also been much used, particularly in the in-air irradiation mode and, again, primarily by Army projects.

A number of facility improvements were completed, primarily to increase the ease of manipulat-

ing the source elements and experiment containers. Modifications to the water system and the radiation monitoring system were begun as a result of experience with the facility; these will be completed early in FY80.

Diamond Ordnance Radiation Facility (DORF). During its 15 years of operation, the DORF pulsed nuclear reactor was used principally for studies of neutron radiation damage in electronic piece-parts, subsystems, and complete electronic systems, to provide information on and to evaluate susceptibility of equipment in the field. The facility was also used for neutron radiography and absolute neutron-flux measurements.

The contributions to our knowledge of neutron damage mechanisms and to the effects of neutrons on military equipment made through the use of this reactor have been invaluable to our present capabilities in these areas. Much of the work done there has joined the permanent literature in these fields.

At the direction of DARCOM, the DORF facility was closed at the end of FY77 and its decommissioning was begun. The first step, disposal of the fuel, was completed on 15 May 1979; 46 of the elements were sent to the University of Utah, and 18 were sent to Pennsylvania State University, both for use in TRIGA reactors. The final shipment of 25 fuel elements went to the Hanford Engineering Company for reprocessing.

Meanwhile, negotiations had been completed on a contract to decontaminate the radioactive areas at the facility and to restore the building to a useful state. This contract was awarded in late FY79; the work should be completed early in 1980.

New Simulation Concepts.

AURORA Modification Project (AMP). The simulation of NWE with laboratory facilities has become increasingly important in recent years. This is a result of the need for frequent experiments and development of data bases that are not feasible on the very expensive and infrequent single-shot underground tests.

A number of new simulators have been installed at HDL, and existing facilities are being radically modified. In the AMP, a water-dielectric pulse-forming line, charged by the present AURORA Marx generator, was designed by Physics International, under a DNA contract, and was installed by HDL and the contractor. Electrical testing of this line was completed in August 1978, and radiation-producing sources were installed shortly thereafter. Radiation testing continued into November 1978. This test series indicated the need for some redesign of the electrical pulse-forming components in the water-dielectric line. Physics International has redesigned the components, and the parts have been fabricated. Installation of the new components was begun early in October 1979, and radiation testing was begun shortly thereafter.

Reflex Triode X-Ray Simulation Program. The basic goal of the Reflex Triode X-Ray Simulation Program is to determine how to construct an accurate simulation of NWE using the physics and technology of intense pulsed relativistic electron beams. This year's work has shown that a dose-enhancement factor of three can be obtained by operating a reflex triode with a thin high-Z anode foil (tantalum) as a multiple-pass thin-foil bremsstrahlung converter. In addition, the spectrum produced by the triode is considerably softer, and hence more realistic, than that produced by a conventional thick-target bremsstrahlung converter. Concurrently, a low-impedance (60-ohm), relativistic (1-MeV), pulsed (100-ns) electron/ion beam source has been designed and constructed for ion beam focusing and plasma heating experiments.

Information Dissemination

Component Response Information Center. Nuclear vulnerability data on semiconductor devices are necessary for the system engineer who must design for a given initial nuclear radiation specification. Such information is also needed in the assessment of the vulnerability of inventory equipment. Since nuclear response testing is expensive and time-consuming, it is important that the results of all tests be disseminated as widely as possible. Such

dissemination can eliminate redundant testing efforts. In recognition of this need, a data base of radiation-effects data on semiconductors is maintained at HDL. This Component Response Information Center (CRIC) is jointly sponsored by DARCOM and DNA. Raw data from experimenters are gathered and entered into the data base. The data can then be distributed in several convenient formats to any DoD agency or contractor. At present, CRIC contains data on nearly 800 transistors and diodes, and on 100 IC's. Data are currently being acquired on 100 new IC types and 50 discrete device types. The distribution of a CRIC Inventory has stimulated many new requests for data and requests for inclusion on the distribution list. A new Data Periodical is being prepared for publication. CRIC continued to be used on every system with nuclear survivability criteria.

Tactical Nuclear Studies

The NWE research program emphasizes the vulnerability evaluation, testing, and hardening of individual components, equipment, and systems. By contrast, the focus of tactical nuclear studies is on evaluating the residual combat capability of selected combat elements during and after postulated nuclear scenarios and on exploring the impact on conflict outcome of this residual capability. The sensitivity of this capability to changes in materiel survivability, tactics, and doctrine is also evaluated.

Theater Nuclear Force Survivability Program. The Theater Nuclear Force Survivability (TNF/S) program is a Department of the Army study, undertaken by direction of the Secretary of Defense, to describe the survivability of theater nuclear-capable units subjected to the full spectrum of combat operations, including conventional, unconventional, nuclear, and chemical attack. The TNF/S study seeks to identify deficiencies in TNF survivability and to develop improvements in this survivability.

Specifically, the objectives of TNF/S are

- to determine the residual combat capability of the TNF in Europe, both before and after a general outbreak of hostilities, with particular emphasis on the residual nuclear-delivery capability,
- to develop feasible alternatives for increasing the survivability of the TNF, including changes in hardware, doctrine, and procedures, and
- to evaluate the impact of the increased residual combat capability of the TNF on the overall outcome of the conflict, with emphasis on the sensitivity to an increased residual nuclear-delivery capability.

To accomplish these program objectives requires detailed evaluations and simulations—using wargaming and analysis techniques—of the probability of enemy target-acquisition systems (current and of the future) detecting dispersed TNF units and of the survivability of the units upon attack.

The US Army Nuclear and Chemical Agency (USANCA) and the Department of the Army Training and Doctrine Command (TRADOC) are the principal program agencies; program management support is furnished by the TRADOC Systems Analysis Activity (TRASANA).

Nuclear Kill Subprogram. The FY79 effort in the nuclear kill subprogram has focused on several assessment and development programs:

- survivability assessments of several Lance Firing Battery configurations,
- EMP vulnerability assessments of several critical radios organic to the Nuclear Release Net,
- airblast vulnerability assessments of vehicles organic to mobile special ammunition supply points (SASP's) and structures for warhead permanent storage (igloos), and
- development of standard TNF/S target arrays for USSR/WP maneuver and field artillery units and identification of critical materiel, organic to these units, for vulnerability assessments in support of the overall TNF evaluation.

During FY79, several Lance Firing Battery configurations were assessed for survivability.[8] Included were the consolidated battery position, battery position area with one and both firing sections out, and a firing section in the hide position. Important parameters considered in the assessment were weapon CEP (circular error probable) and target location error. Critical vulnerabilities were identified and used in an investigation[9] of the residual combat capability of these units. Study results[10] indicate that mission capability can be improved by several techniques.

Vulnerability assessment of TNF equipment was a major activity in FY79. EMP vulnerability assessments were completed for the AN/TRC-110/117, -112/121, and -138 multichannel radios and the SB-22 switchboard.[11] With these data for the radios, vulnerability data now exist for all equipment organic to the Nuclear Release Net. Airblast-induced overturning calculations were made for vehicles organic to typical mobile SASP's. Included were the M38A1, M35A2, M881, M814, and M818 trucks, the M819 tractor/wrecker, the M127A and M172A1 semitrailers, and the M488 forklift. In addition, airblast vulnerability estimates of damage—arch collapse and door/end-wall blow-in—to a typical European nuclear storage site igloo were developed from existing vulnerability data. Finally, airblast overturn vulnerability estimates were made for the two US Army nuclear-capable self-propelled howitzers—the M109A1 and M110. Resulting probability-of-survival curves have been calculated for these TNF equipment items.

A report[12] was published, in final form, of the Vulnerability Data Array—the TNF/S NWE vulnerability data base for major US/NATO land combat systems that are deployed in Europe. Included in the array are vulnerability data for wheeled vehicles, tracked vehicles, communications and electronics equipment, weapon systems, target-acquisition and surveillance equipment, and missile systems.

Command, Control, and Communications Degradation (C^3/D) Subprogram. Essential to any military operation is the ability to command, control, and communicate. This is especially true for US and Allied forces who are expected to fight and win against a numerically superior threat force. Current doctrine strongly emphasizes the necessity to perceive the battlefield accurately at each echelon in order to place the maximum fire power at the critical points on the battlefield at the critical times, to defeat an attack or to penetrate enemy defenses.

To effectively evaluate the degradation of C^3 and its influence on the overall outcome of the battle, the C^3/D subprogram has been divided into three major phases.

- definition phase—the development of a complete C^3 data base
- modeling phase—the construction or enhancement of computer models
- analysis phase—the application and analysis of the data base and models

The definition phase, completed during FY79, consists of the collection and development of the

[8] *C. Spyropoulos, An Assessment of the Survivability of the Lance Firing Battery to Warsaw Pact Tactical Nuclear Weapons, presented at the 42nd MORS Meeting, Naval War College (5 December 1978).*

[9] *J. Wicklund, Mission Performance of a Lance Firing Unit After a Nuclear Burst, presented at the 42nd MORS Meeting, Naval War College (5 December 1978).*

[10] *C. Spyropoulos, J. Michalowicz, and R. G. Moore, An Assessment of the Survivability of the Lance Firing Battery to Warsaw Pact Tactical Nuclear Weapons (U), Harry Diamond Laboratories, HDL-PRL-78-13 (June 1978). (SECRET)*

[11] *J. Vallin and K. LePoer, Low-Altitude Burst EMP Assessment of the SB-22(*)/PT Manual Switchboard as Used for Internal Communications in a 155-mm Howitzer Battery (U), Harry Diamond Laboratories, HDL-PRL-79-9 (May 1979). (SECRET)*

[12] *W. Vault, Vulnerability Data Array—The Agreed Data Base: Final Report (U), Harry Diamond Laboratories, HDL-PRL-79-13 (June 1979). (SECRET)*

following data items for echelons from corps and below:

- command and control structure and functions,
- doctrine and procedures,
- communication networks, and
- communication requirements and equipment for each functional combat system.

The final products of the definition phase are diagrams of the communication networks, identification of all communication equipment and personnel for each communication network, and determination of the personnel, equipment, and times needed for performing command and control duties at the command posts for the several echelons. These latter estimates were derived in part from Army Training and Evaluation Program (ARTEP) documents, as well as unit Standard Operating Procedures (SOP's) and the results of field test exercises.

Much of the above data has been included in a unique data base under control of the data manager System 2000. Applicable portions have been extracted and distributed to other TNF/S subprograms.

The set of information developed in the definition phase forms the basis for the modeling phase of the C^3/D study. This phase consists of three major tasks:

- construction of the TACNET model,
- construction of the CONDUCT model, and
- modification of the TACWAR model.

TACNET is a computer simulation model of the European Army Communications Networks. The program is written in the General-Purpose Simulation System (GPSS) language. TACNET represents the configurations of the networks as described in the 1974 INTACS EAD Study. The model takes into account priority levels and preemption, and it has a rudimentary representation of the personnel operating the different command posts. TACNET is used to obtain statistics on the C^3 degradation that occurs when links and nodes comprising the networks are eliminated and when personnel are attrited. In particular, these statistics are gathered for messages that originate or reach their destination at division headquarters, and for messages that form a chain corresponding to nuclear release activities. The results from TACNET have been incorporated into TACWAR, described below.

The CONDUCT model, currently being developed, incorporates the data generated during the definition phase, together with an alternative routing and command structure, into a discrete event simulation model. The model simulates C^3 elements at echelons from division and below, with special emphasis given to the C^3 associated with nuclear release and targeting. CONDUCT allows for the study of the impact of selected or general C^3 degradation on the conduct of the battle.

The theater-level TACWAR computer model, originally developed by the Institute for Defense Analysis (IDA) for the Systems Analysis and Gaming Agency (SAGA), has been modified to include C^3 degradation effects. Specifically, the decrease in the total combat effectiveness for divisions due to C^3/D has been included, based on results obtained from the TACNET model described above. In addition, the reduction of available nuclear-delivery systems, the increase in the nuclear authorization delay time, and increase in target-acquisition processing time due to C^3/D have been included in the modified version of TACWAR. This modified TACWAR is available as an analysis tool to aid in the Net Assessment subprogram of TNF/S.

Fighting Unit Survivability Evaluation. Historically, the decision to harden a critical battlefield system to NWE has been based on the piecemeal selection of systems that were readily adaptable to established nuclear hardening criteria, with little rationale for hardening levels selected. To assist

decisionmakers in the selection process requires a methodology that embodies a rationale based not only on enhanced survivability but also on increased military effectiveness of the force. The objectives of the Fighting Unit Survivability Evaluation (FUSE) program are (1) to relate battlefield effectiveness of small tactical units to increased NWE survivability as a function of materiel hardness level (alternative criteria) and hardening cost, and (2) to provide nuclear hardening decisionmakers with a basis upon which nuclear hardening decisions can be made, with a high degree of confidence that survivability will be enhanced.

The assessment of alternative criteria proceeds by means of a cost trade-off analysis. The nuclear excursion of the SCORES scenarios—Europe II, Sequence 3—has been laid out, and typical Red threats—including weapon allocation—have been determined. An assessment of damage of the battlefield system under study, for various hardness levels, is performed on the modeled battlefield with the HDL nuclear damage assessment computer code (NUDACC). Suggestions are formulated for enhancing the survivability where required. BRL's Residual Combat Capabilities (RCC) computer code is used to evaluate the contribution of either materiel hardening or operational changes to increased military effectiveness of tactical units and their survival. Finally, a cost trade-off analysis is performed to compare the cost-effectiveness of the various alternatives for enhancing survivability.

The study has produced a rationale for selecting suitable candidate systems for nuclear hardening, based on a rating scheme that incorporates the following considerations:

(1) Blue system criticality,
(2) Red target-acquisition probability,
(3) Red nuclear targeting priority,
(4) probability of bonus damage,
(5) unit cost,
(6) density on the battlefield, and
(7) state of development.

The TACFIRE system, the field-artillery fire-support C^2 computer system integrated with Division Artillery, was selected as a suitable vehicle for testing the FUSE methodology.

Results of the assessment and recommendations for increasing the effectiveness of division artillery and enhancing the survivability of the TACFIRE system are given in a final program record.[13]

Nuclear Weapons Effects Thermal Survival Probabilities. Methods presently used to evaluate thermal damage to materiel and personnel casualties due to a nuclear burst can lead to poor decisions by military field commanders and weapon planners. A factor that is ignored in these methods is that the transmissivity of the atmosphere varies sharply with local weather conditions. What have been available are three curves which give the transmission factor as a function of range for "good," "average," and "poor" atmospheric conditions; estimates of the thermal fluence can vary as much as an order of magnitude, depending on the condition assumed. With such large variation, the computation of the most probable value of thermal fluence that results from a nuclear detonation has been impeded.

Research on thermal survival probabilities developed a method for manipulating data on the atmospheric transmission factor for thermal radiation from a nuclear weapon to give the probability that a given thermal fluence will be exceeded for a battlefield element (unit, town, etc) at a given distance from designated ground zero. This method yields the most probable fluence: in most cases, these values are significantly different from those

[13]K. Sweasy and J. Michalowicz, Fighting Unit Survivability Evaluation (FUSE): TACFIRE System Analysis (U), HDL report (to be published). (SECRET)

calculated with "average" weather conditions (see fig. 6).

The specific climatic conditions of northwest Europe—statistical variation over a year—were used. Simple cumulative lognormal distributions were obtained which were generalized into formulas from which the probability that a given thermal fluence is exceeded can be calculated for any combination of weapon yield, separation, and delivery error (delivery system and target location error). These formulas were further simplified for the error-free case and a convenient nomogram was obtained; a rule-of-thumb formula is available for rough calculations.

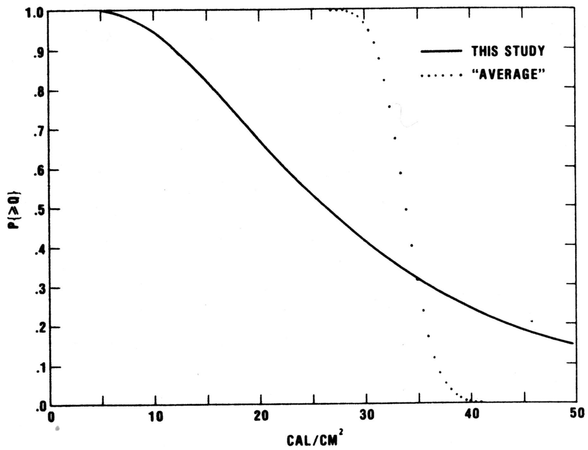

Figure 6. Thermal fluence 4 km from 300 kT (σ = 0.1).

fluidics

Eighteen years ago, fluidics was conceived by HDL employees, who invented the fluidic amplifier and many of the devices necessary to build fluid control systems. Fluidics is a way to build sensing and control systems with no moving mechanical parts, thus producing systems with low initial cost, high reliability, and little or no maintenance. These attractive features have thrust fluidic devices into the industrial marketplace, where fluidic shower heads, lawn sprinklers, oral irrigators, respirators, and air-conditioning controls are readily available from commercial sales outlets. Fluidics is also emerging as a viable technology in military systems, where high reliability and low life-cycle costs are important.

Lead Laboratory for Fluidics Technology

HDL is DARCOM's Lead Laboratory for fluidics. In carrying out this responsibility, HDL conducts and technically manages both a 6.1 research and a 6.2 exploratory-development program. The objective of these programs is to create the technology base necessary for the scientific and engineering application of fluidics, so that low-cost, highly reliable fluid control systems will be available for Army needs.

Early attempts at developing and building fluidic systems were greatly impeded by the lack of an adequate design theory; experimenters had to design and build by "cut-and-try" methods. These early attempts were also hampered by the lack of sensors and components with the characteristics required to meet system needs. Consequently, considerable research has gone into component conceptualization and into analysis and synthesis techniques for the design and optimization of fluidic components, circuits and systems.

Technology transfer of fluidics is one of the objectives of the Lead Laboratory. In this capacity, HDL staff members assisted numerous government agencies with fluidic system development. As an example, in FY79, HDL assisted the Tank Mobility Action Team in technical programming; assisted the Navy on manufacturing methods of fluidic systems, pilot ejection seats, and backup flight controls; and acted as technical monitor on three separate Tank-Automotive Research and Development Command (TARADCOM) programs.

Exploratory Development

Turret Stabilization. The most significant event in fluidic development in FY79 was the successful demonstration of stabilizing the main gun of an armored combat vehicle. The purpose of the system is to assist the gunner in maintaining accurate gun alignment at the target while the vehicle is traversing rugged terrain, receiving numerous disturbances. The demonstration, conducted in April 1979, showed that the fluidic system met the performance requirements of the current fielded system on the M60 tank.

Because of the inherent ruggedness and reliability of fluidic components/systems, the fluidic stabilization system could significantly lower the life-cycle costs of presently fielded systems. Another added advantage is the lower initial cost of the fluidic system. These advantages are due to the laminar jet rate sensor and amplifier gain block. Angular rates as low as 0.2 degrees per second were obtained and forward gains of over three million were used on the stabilization system.

The actual demonstration used a modified M48A5 tank with an add-on stabilization system. In attendance were staff members from ERADCOM, TARADCOM, ARRADCOM, and the Navy (see fig. 1). Demonstrations were also presented to other government and industry officials.

Figure 1. Demonstration of tank turret stabilization.

The significance of the fluidic stabilization project is that it marked the first time that laminar flow devices, the second generation of fluidic componentry, were used in a major system. Problems like offset, power-supply conditioning, and dynamic compensation had to be overcome for the successful completion of the effort. These second-generation devices will significantly enhance the capability and use of the technology in solving military problems, especially where reliable, low-cost systems are desired.

Heading Reference. As a direct spin-off of the turret stabilization project described above, a new program was initiated in FY79. The purpose of this program is the development of a fluidic heading reference unit (FHRU) for armored vehicles. The objective is a low-cost, reliable FHRU, accurate to 1 degree per hour. The high performance requirements of heading reference units demand significant advances in the state of the art. As an example, the noise thresholds of the laminar jet rate sensor and gain block have to be reduced three orders of magnitude over that required for stabilizing turrets.

The research effort, redirected to the FHRU needs, resulted in significant advances in rate sensors, laminar amplifier gain blocks, null offset reduction, and power supply conditioning. As an example, figure 2 shows the output of a laminar jet sensor and gain block based on the turret stabilization project (FY78). The second trace in figure 2 shows a recorder plot for the current sensor/amplifier package. The third trace is also an actual plot of the current package. Note that the scale on the third trace has been expanded 50 times over the first two. The threshold of the current fluidic component is ± 0.002 degrees per second, or an improvement of about 100 times over last year's threshold measurement. The ± 0.002 degrees per second is approximately half the earth's rate of rotation.

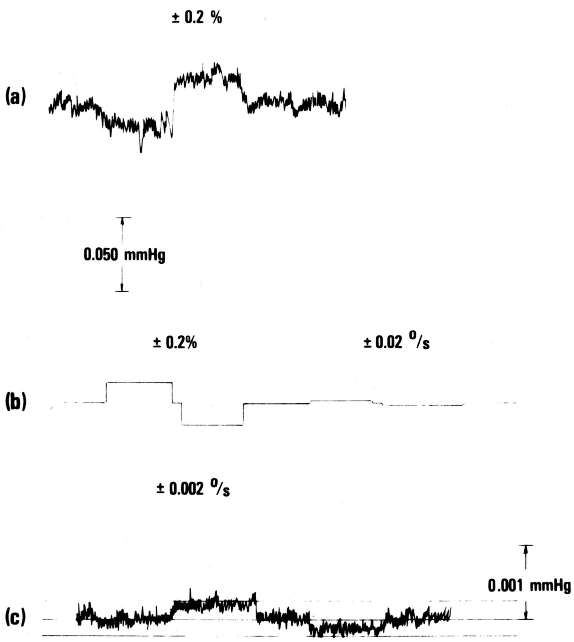

Figure 2. Output traces: rate sensor/gain block.

Backup Fuel Control. Although electronics provides good performance and cost effectiveness for complex gas-turbine engine controls, the severe operating environment of military vehicles and aircraft raises concern about electronic reliability in areas of sensing and computation. Although fluidic controls in their present state cannot perform as accurately as electronic controls, fluidic controls are excellent as backups to significantly increase battlefield survivability. The following are a few of the reasons for using fluidics as backup fuel controls:

- high reliability
- cost-effectiveness
- dissimilarity of technology
- availability of power supply
- acceptability of backup mode performance
- immunity to high shocks, vibration, and electromagnetic/nuclear radiation

A project was initiated to conceptualize a fluidic backup fuel control. The Industrial Turbines International GT601 gas-turbine engine was selected because of its availability. The present emphasis is on developing the critical fluidic computation and control switching logic in the failure detection circuit.

Shaft Speed Sensor. An accurate and reliable speed sensor is required to control the speed of some rotating equipment. Fluidic control systems require a high signal-to-noise ratio, along with the ability to be sealed from any contaminating environment. An example of the need for a speed sensor is in a fluidic fuel control system for a gas-turbine engine. The sensor accuracy required for the engine is $\pm 1/4$ percent. Although this accuracy was achieved for the turbine fuel-control project, the sensor used has moving mechanical parts and is the "weak link" in the system.

Initial efforts to use an eddy current device were not successful because of eddy current heating problems in the materials. MERADCOM is currently developing a device called the vortex speed sensor. The temperature effects in the vortex device will be due to changes in gas viscosity rather than material heating.

Semiactive Adaptive Damping System. Hardware developed under the TARADCOM contract has shown the capability of varying the damping of a shock absorber by a factor of four. Such changes in damping will extend the life of military vehicle shock absorbers under off-road conditions. This will also improve the speed and control of a vehicle as it operates on rough roads or off the road. The capability of the fluidic damping valve will be studied in the near future under simulated actual-ride conditions at the TARADCOM test facilities at Warren, MI.

Traction Transfer. A study has been initiated by TARADCOM to investigate the feasibility of using fluidics to control the applied torque to the driving wheels of a truck to limit wheel slip in mud, snow, and ice. Such a system will provide increased mobility in poor road/off-road conditions. By decreasing the number of vehicles that are disabled in such conditions, the system will also reduce the manpower requirements associated with recovering these vehicles.

Servovalves. Fluidic input servovalves are necessary components of fluidic control systems requiring power actuation. These valves have been the subject of continuing study by government, university, and industrial engineers to improve their performance, power consumption, and reliability, as well as to lower cost. A program has been initiated for industrial development of a two-stage dual-input (fluidic and electronic) servovalve, so that fluidic systems can interface with electronic computer-controlled fluid power systems. The two-stage servovalve under consideration consists of a first-stage fluidic amplifier and a second-stage spool valve. The fluidic signal is applied to the input port of the fluidic amplifier, and the electrical signal is applied by a torque motor to a moving member in the interaction region of the amplifier. The deflection of the power jet and the resulting differential output pressure is due to the summation of the fluidic deflection at the power nozzle exit and the electronic deflection in the interaction region.

Another industrial program has been initiated to determine the feasibility of direct-drive (fluidic

and electronic) servovalves for use in a fluidic backup flight control system. The use of control-by-wire or fly-by-wire flight and thrust control systems requires dissimilar backup systems for high aircraft survivability characteristics. Four servovalve configurations are being evaluated.

Temperature Sensing. With increasing emphasis on energy conservation, more accurate and reliable techniques for temperature measurement are being sought by many high-temperature process industries, as well as the Army. In certain processes such as steel making, magnetohydrodynamic power generation, and close-proximity nuclear reactor applications, no means at all exist for continuous high-temperature measurement. The ability to continuously measure temperature accurately and reliably in these processes could result in enormous energy savings. Attendant to this energy savings would be the obvious cost savings and improved quality.

In FY78, preliminary field evaluation of prototype systems showed successful operation for ignition detection in a marine steam generator (1650°C) and measurement of Army munition forging furnace temperatures (1300°C). With the knowledge gained, the first *one-piece* probe was designed and fabricated of three different materials in FY79; the materials used were high-purity alumina (1750°C), magnesium aluminate (1700°C), and yttria stabilized zirconia (2100°C). Each of these materials offers a solution to a specific set of application requirements. Currently, the new one-piece design is being fabricated of alpha-sintered silicon carbide. With silicon carbide's superior thermal shock properties, the possibility exists for the first time of *continuous* temperature measurement in molten steel. Five complete fluidic temperature-sensing systems have been built for industrial service. After calibration at the National Bureau of Standards, these systems will be evaluated in actual industrial applications such as Army munition plants.

Fluidic Wing Leveler. Expendable aircraft, such as decoys, drones, and targets, must of necessity be low-cost items but still highly reliable. In addition, when remotely piloted vehicles (RPV's) are used for the programmed collection of battlefield meteorological data (as opposed to random collection by a balloon, which is unprogrammed), they must be salvageable and cost effective compared to a manned craft. For this reason, RPV's require low-cost autopilots.

The single most important component of an autopilot is the wing leveler, essentially a stability augmentation system. Such devices are generally based on an inertial or a rate gyroscope whose cost is usually equal to or greater than the desired cost of the RPV system itself. Fluidic rate sensors have shown inertial flight qualities and cost considerably less than comparable gyros. With this in mind and in support of the micrometeorological data-gathering mission of ERADCOM's Atmospheric Sciences Laboratory (ASL), HDL has designed, built, and flight-tested successfully a single-axis, fluidic wing leveler on a 2.6-m wingspan radio-controlled aircraft, shown in figure 3. Characteristics are a rate threshold of less than 0.1 degree per second, 1-V output for 50 degrees per second, and low cost (in the order of a few hundred dollars).

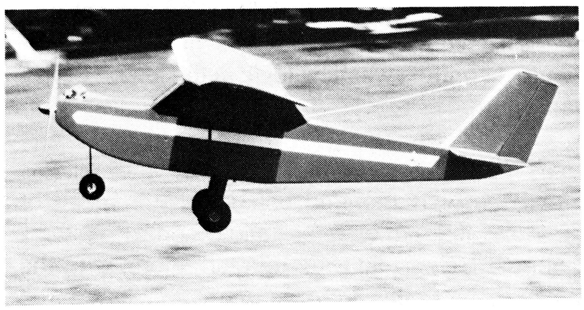

Figure 3. Test aircraft for fluidic wing leveler.

Fluidic Mud-Pulse Telemetry. The general objective of the USGS-sponsored fluidic mud-pulse telemetry investigation is to develop a reliable way to quickly identify the onset of down-hole conditions which ultimately could lead to loss of well control and a blowout. The specific objective is to develop a reliable valve for producing coded pressure pulses in the fluids (muds) normally used to circulate cuttings to the surface. Although 25 percent of all industrial drilling research is directed towards bore-hole measurements while drilling, with emphasis on mud-pulsing techniques, the technology has not

produced a suitable bore-hole data-transmission link.

During FY79, fluidic mud-pulsing circuit models were designed and operated under simulated bore-hole conditions at HDL. Initial results showed the non-Newtonian properties of drilling fluids to have little effect on the functional characteristics of sub-scale test circuits. The mud-pulser investigations will continue in FY80 to cover the design of a full-scale pulser (fig. 4) for test and evaluation in a well.

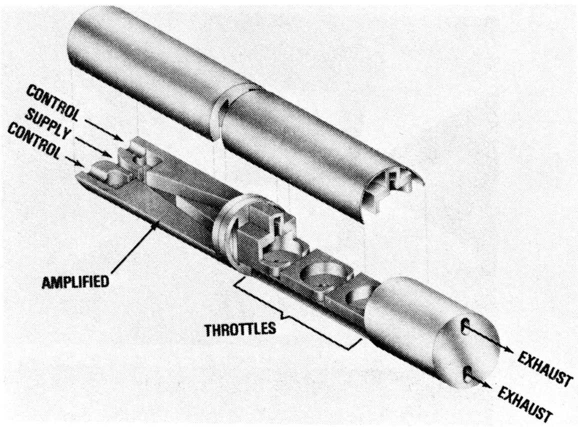

Figure 4. Full-scale mud pulser.

Manufacture of Fluidic Components by Cold Forming. Cold forming uses dies and punches to form and shape a part at ambient temperature or at moderately elevated temperatures. The advantage of this method is that consistent, precise, low-cost parts can be mass produced, and inspection can be done on a statistical basis, further reducing piece-part costs. Previous work demonstrated the feasibility of using cold forming by producing a small number of fluidic amplifiers with highly consistent fluidic functions.

A new effort, initiated in FY78 and continued in FY79, explored the cold forming of fluidic amplifiers through a technique known as fine blanking. Fine blanking produces very consistent components and essentially eliminates the problem of internal stress generated by other types of cold-forming processes. The effort, funded through the Army's Manufacturing Methods and Technology program, is multi-phase. The first phase consists of the production of selected dies based on modifications of HDL's standard laminar proportional amplifier. These modifications were required to increase tool life and still maintain fluidic component performance. A team of HDL employees was formed to advise design engineers on proper trade-offs. After several iterations requiring computer algorithm outputs verified by experimental data, a final design was selected and corresponding dies produced. The fabrication of the dies was completed late in FY79.

The next phase, currently in progress, involves the production of parts from the selected tools. Parts will undergo dimensional and functional tests to verify proper and consistent fluidic performance. The effects of burrs and die roll on functional performance will be examined. In addition, components will be bonded together to determine the compatibility of the bonding process with the fine-blanking manufacturing method.

Research

LPA Dynamics. Basic research in laminar flow has led to the development of wide band-pass amplifiers and frequency-to-analog converters; these developments have produced an order-of-magnitude increase in the dynamic range of such devices as fluidic chopper-wheel speed sensors. Figure 5 shows a plot of dc output pressure versus frequency of a frequency-to-analog (F/A) converter operating at a base frequency of 6.7 kHz. A maximum linear signal change of about 3-mm Hg with a discrimination of about 0.005-mm Hg yields a dynamic range of 600, or the ability to detect less than 1 Hz of change to a maximum of 400 Hz.

The analysis of the dynamic characteristics of laminar proportional amplifiers (LPA's) has led to a model that includes internal flow and acoustic feedback. This model has accurately predicted the high-frequency resonances often found in high-aspect-ratio devices. Interestingly, these resonances have been related to the edgetones given off by a jet

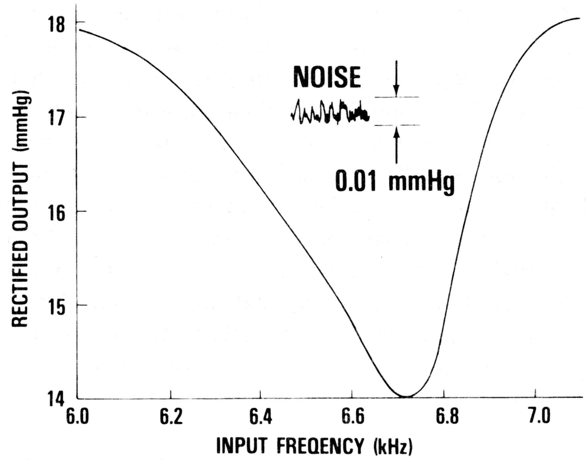

Figure 5. Output of frequency-to-analog converter.

impinging on a wedge, and the ratio of the LPA feedback resonance eigenfrequencies is almost exactly that observed by fundamental researchers. Figure 6 shows a computer plot of the frequency response (Bode plot) of a highly resonant LPA as generated by the current model. The ratios of the peaks correspond within 10 percent to data on edgetones in the literature, and the response itself is very close to that of an actual LPA. Follow-on efforts will include taking this symmetrical, differential model and considering nonsymmetry, nonlinearities, and acoustic matching effects of multiple devices.

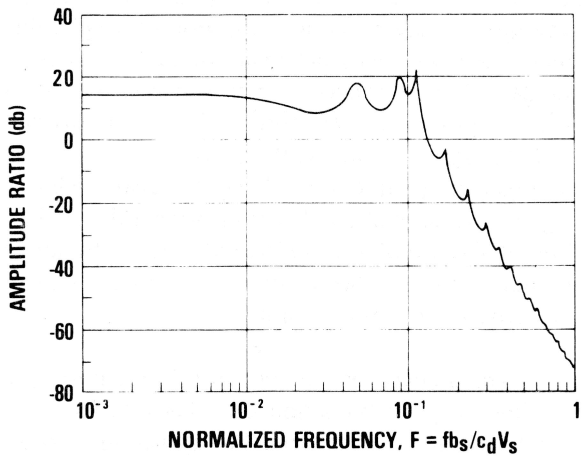

Figure 6. Bode plot of LPA frequency response.

Flow Visualization. Flow visualization is an excellent technique for observation of time-dependent phenomena, since the time scale is slowed by a factor of almost 1000. In such a manner, all the nuances of the flow may be observed and modeled. The present flow-visualization apparatus is a large-scale water table that permits scaling of up to 20×. Bright-colored neutral-density food dyes are injected into the stream and flow fields to enhance contrast. A single-pass, back-lighted mirror system is available for photographic recording. In the current studies involving LPA amplifier dynamics, there is considerable usage of flow visualization techniques. As an example, figure 7 shows a sequence of photographs of a single cycle of oscilla-

(a)

(b)

(c)

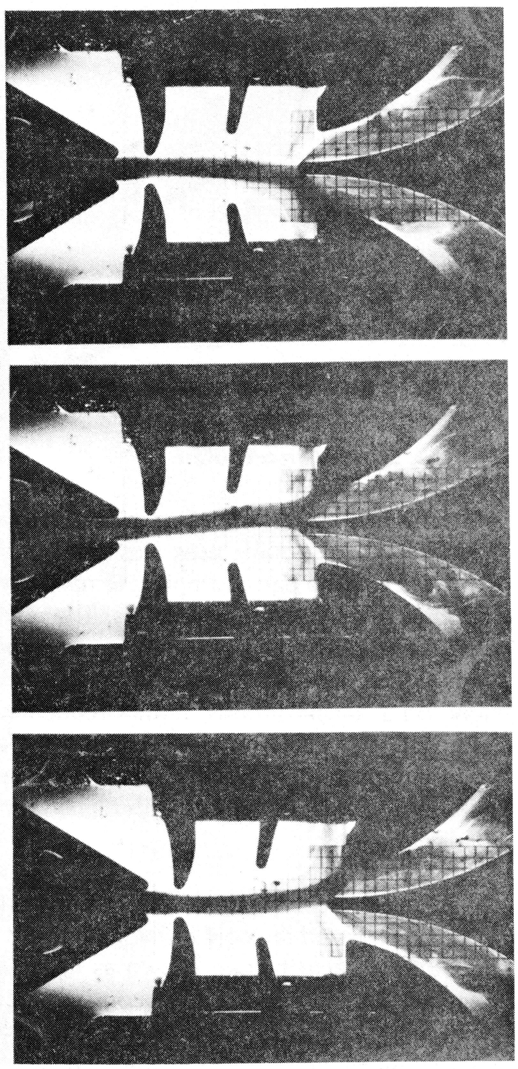

Figure 7. Oscillation cycle.

tion as found in a pressure-controlled oscillator that is being considered as a pressure-to-frequency interface from fluidic sensor/preamplifier circuits to electronics.

Rate Sensor/Gain Block. Further refinement of the staging techniques and operating criteria developed by HDL has improved the signal-to-noise ratio in the rate sensor and amplifier from 2.5 to 100. At the same time the threshold and resolution have been lowered from 0.2 to 0.002 degrees per second, enabling these devices to sense the earth's rotation rate. These accomplishments have been reached by carefully selecting the operating Reynolds numbers of all components in the package (rate sensor, amplifiers, and dropping resistors), and through the use of components exhibiting very low null shift (less than 1 percent maximum).

Compensation Methods. Significant results have been achieved in both temperature and null-offset compensation research. The combination of both the temperature and null-offset research efforts has extended the operating temperature range of both the LPA and the laminar jet angular rate sensor (LJARS) with little or no performance degradation.

Temperature Compensation. Even though the methods of linear resistor bypass and bias pressure control have reduced the temperature dependence of operating characteristics significantly, fluidic systems still cannot operate over the entire military temperature range, −40 to 180°F, without degrading performance. In order to extend the operating range of the fluidic system, a power-supply conditioner has been designed and tested (fig. 8). It consists of two concentric cylinders which are made of materials with different linear thermal coefficients of expansion, so that the width of the flow passage is a function of the fluid temperature. As a result, the operating Reynolds number remains fairly constant over the entire military temperature range. Figure 9 shows the compensated and uncompensated sensitivity of the LJARS. This power-supply conditioner also prevents the flow in the fluidic system from going into turbulence at low and high temperature for pneumatic and hydraulic operation, respectively.

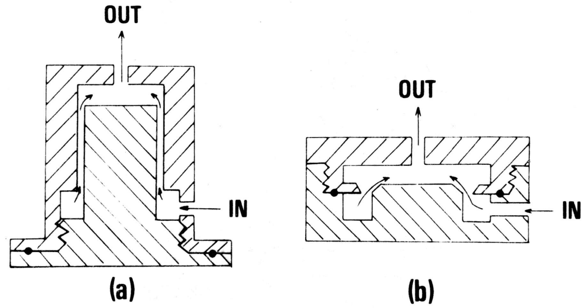

Figure 8. Power supply schematic.

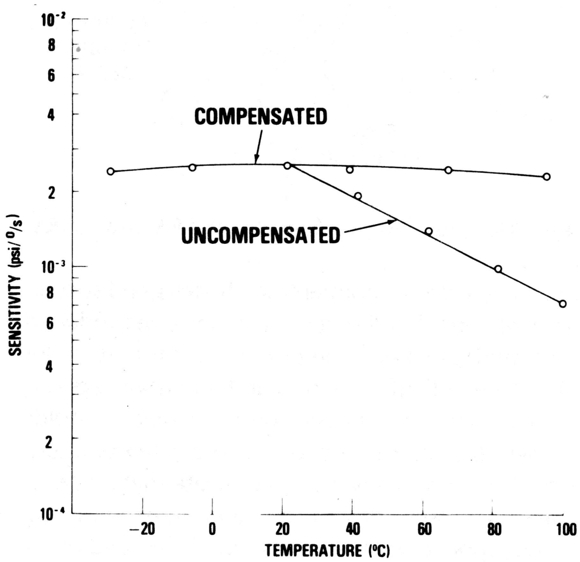

Figure 9. Sensitivity of LJARS.

Null Offset Compensation. Null offset and drift can also impose limitations on the LPA and LJARS. The use of fine blanked laminates has proved to be an effective way of reducing the null offset. This method, however, does not allow for the fine tuning of the system so that the null offset can be set to zero at the operating point. Therefore, it would be ideal if the effectiveness of the fine blanked laminates could be combined with an adjustable means of fine tuning. Figure 10 shows a schematic of the new design configuration of the LPA and LJARS. In this new configuration, the main supply jet is formed by summing two supply jets; each supply jet has an adjustable bleed resistor. As a result, the main supply jet can be steered by adjusting the appropriate bleed resistor. Figure 11 shows a typical null offset trace of the new-design LJARS

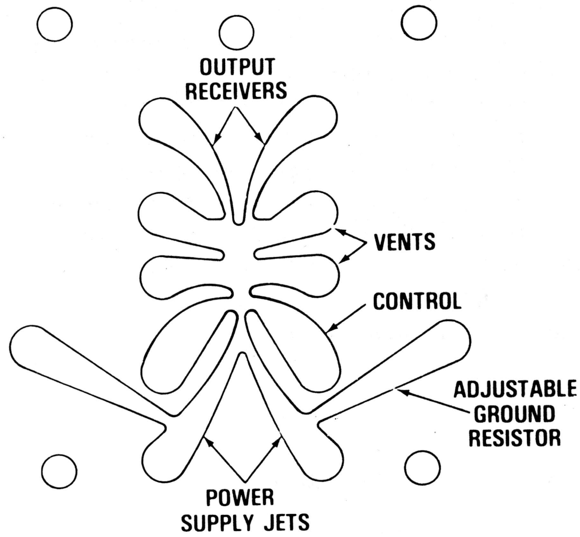

Figure 10. New design schematic of LPA and LJARS.

compared with the conventionally designed sensor. It can be seen that the null offset has been reduced significantly. It should be pointed out that in order to hold the null offset at zero at the operating point, it is necessary to maintain the operating Reynolds number fairly constant over the entire temperature range. Preliminary test results indicate that by combining the new design configuration with the power-supply conditioner, the null offset and other performance characteristics can be maintained at very close to a constant level over the entire temperature range.

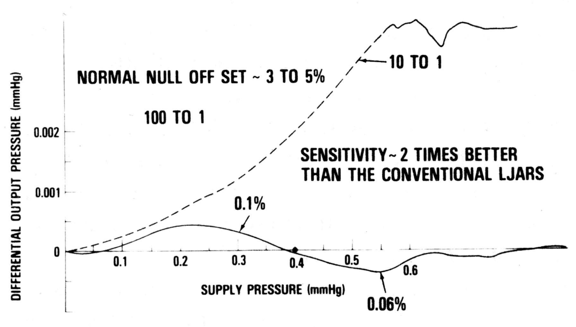

Figure 11. LJARS offset trace.

Flow-Induced Oscillations in Cavities. A study to determine the feasibility of using pressure oscillations in shallow cavity flows as a fuzing signature has been completed. Distinct modes of pressure oscillations occur in cavity flows. The study shows that the oscillations depend on the cavity width (rather than depth), Mach number, and shear layer thickness.

Experimental data in the subsonic region were obtained for axisymmetric cavities cut in a model having the standard contour for artillery fuzes. For freestream velocities ≥ 500 ft/s, results show that cavity oscillations occur for cavities farther than 1.25 in. from the nose of the ogive for cavity widths ≥ 0.25 in. and depths ≥ 0.05 in. At angles of attack between 0 and 6 degrees, large circumferential variations of the rms pressure fluctuations were observed; however, relatively strong fluctuations always occurred at some location.

Fluidic Generator. A project was initiated to develop a mathematical model of the onset of sustained oscillations in a short-tube, knife-edge, cavity configuration over subsonic and supersonic regimes. This research would provide general support for many tri-service fuzing applications, including the GSRS fluidic generator.

Approximately seven months after the study was initiated, an urgent need arose for a more detailed mathematical model of the fluidic generator than previously proposed. The desired model would incorporate all the aerodynamic effects, including heating of the air in the generator, and provide for a wide range of changes in geometric parameters of the generator. Moreover, the model must be completed so that many fundamental questions can be answered, such as (1) the overall efficiency of the device, (2) whether it could be forced into unwanted modes of operation, and (3) the adequacy of the present laboratory procedure for testing the generators. Because of the urgency of the need and the detailed nature of the desired mathematical model, the Jet Propulsion Laboratory (JPL) was asked to develop the model.

The fluidic generator operating frequency is the result of the interaction or coupling of at least three individual fluid oscillator mechanisms, potentially interacting over a wide range of fluid veloci-

ties, densities, and temperatures. The oscillator mechanisms are (1) jet instability or oscillation, (2) Helmholz resonance (or oscillation), and (3) diaphragm oscillation. Each of the oscillator mechanisms has fundamental and higher frequency modes of oscillation. The combined oscillator system consisting of these three oscillator mechanisms can be described as a feedback control system. The forward gain is provided by the fluid jet itself. Pressure feedback signals are generated by sonic reflections from (1) the knife edge in the cavity (possibly ring tones), (2) the Helmholz cavity (assuming that the diaphragm is not moving), and (3) the moving diaphragm. The coupling or summation of these three feedback signals is the most crucial aspect of fluidic generator operation. JPL is conducting experimental studies on the generator to determine the nature of the coupling as a first step in its effort to develop a mathematical model of the generator.

surveillance and target acquisition

Radar Technology. A major thrust in ERADCOM's ISTA (intelligence, surveillance, and target acquisition) mission is the development of the technology base in support of personnel- and vehicle-detection radar. The objective of this program is to provide the radar technology for low-cost, automatic, reliable battlefield surveillance and target-acquisition systems with the capability of all-visibility operation, foliage penetration, reduced electronic countermeasure (ECM) vulnerability, and increased battlefield survivability.

A new task was initiated in FY79 aimed at developing technology for a multistatic battlefield-surveillance and target-acquisition radar. Increased concern over the vulnerability of tactical radars to electronic location and to anti-radiation missile (ARM) attacks has led to consideration of a tactical multistatic radar system to perform the surveillance and acquisition mission. A multistatic radar configuration, employing several noncolocated transmitters and receivers, will reduce the vulnerability of these systems, since the source of radiation can be removed to a relatively safe position, while leaving the receiver in the weapon-delivery system or on the surveillance platform. The use of the multistatic radar approach also minimizes catastrophic loss, much as a phased-array antenna continues to be effective despite the loss of several elements.

Two types of multistatic radars are being examined. The first is a pulsed microwave system requiring multiple dispersed transmitters, but a single receiver. The processor and display are located at the receiver, which may be vehicle mounted. The same set of transmitters may of course serve a number of independent receiving units.

The receiver incorporates a multiple-beam antenna which simultaneously looks in all azimuth directions. Each beam feeds a separate processing channel, which permits both angle and time-of-arrival measurements to be made. The transmitters emit pulses sequentially. They may either transmit omnidirectionally or, as a refinement, the "master transmitter" may transmit over a scanning beam.

The receiver sees the direct transmission from each transmitter as well as the signal reflected by each target, and thus measures path-length differences for each transmitter for a given target. Although the transmitter and receiver locations may not be known, these path-length differences plus the angle measurements enable the processor to locate targets relative to the receiver position. A moving-target indicator (MTI) is also incorporated in the processor.

This system thus provides the radar information at the passive receiver unit. Directional jamming sources are ineffective since the receiving antenna is separated from the transmitting antennas. Of course, the radar coverage provided is limited to the common coverage of the participating antennas.

The second type of multistatic radar is more like a "modulated cw" system, and operates in the

high-frequency band. Primarily by surface-wave propagation, a remote transmitter floods the area of interest with long-wavelength energy. The field distribution is perturbed by the target reflections. The resultant distribution is sampled at various points by a network of dispersed omnidirectional receiving elements, which telemeter the information to the processor. The processor attempts to derive the target positions from knowledge of the sample values. An MTI circuit removes the effects of stationary reflectors from the samples.

The processing problem is similar to that of determining target position with a large array of antenna elements, except that here the antenna "aperture" is extended in range also, is extremely undersampled, and is excited by targets that lie within the aperture itself; the device must therefore examine positions rather than merely directions to targets.

The long wavelengths employed reduce terrain masking and increase foliage penetration. However, unless the fractional bandwidth transmitted is large and/or a large number of receiving units are deployed, the total information obtained may be low. In any event, the signal processing is a formidable task.

Both investigations are still in their initial stages. Conceptual design and computer modeling constitute the bulk of the present work. It is planned for FY80 to select and design in detail one or more systems that show promise. During FY81 and FY82, a brassboard system will be fabricated and evaluated in the field test.

Installation Security Radar. The FY78 edition of this report described the XMISR in considerable detail. Briefly, the Installation Security Radar (ISR) Project is an advanced development task to investigate the application of radar technology to the security and protection of DoD bases and installations. The sponsor is the Base and Installation Security System Program Office (BISSPO), an Air Force-managed, tri-service office with responsibility for developing hardware for the security of DoD bases and installations.

HDL delivered the ISR to the Pantex plant in Amarillo, TX, in April 1979, and completed the shakedown of the radar in June 1979. HDL and Sandia Corp. are jointly evaluating performance, collecting real time data, and testing the effect of improved signal-processing and target-tracking algorithms.

HDL is evaluating several possible modifications to the ISR that will extend its detection range to 5 km without degrading its nuisance target handling capability.

Target Classification. A target classifier has been developed for use with the Installation Security Radar system to separate threat target (human, vehicle), nuisance target (animal, bird) and false target (windblown foliage, power-line) returns. Six essential spectral features were derived from a simplified target backscatter model. Each feature was assigned a probability density function based on physical constraints and empirical results. A probability assessment is made that a given return is due to each of the target classes based on estimated values of each of the spectral features. Preliminary results suggest an approximately 90-percent probability of correct classification for high signal-to-interference return on a single-cell basis. Track or multiple-cell classification is expected to yield high-confidence target assessment.

Error Bounds and Terrain Models for Optimization of Radar Performance in the Presence of Clutter. Lower bounds on mean square error (MSE) of range and/or Doppler estimates are used as a measure of radar system performance for a terrain clutter environment. Terrain modeling and radar system parameters are used to generate statistics of the clutter process so that maximum likelihood range and/or Doppler estimates may be obtained. Cramer-Rao and Barankin lower bounds are then applied to these estimates. Maximum likelihood estimation of some unknown, nonrandom parameters of the terrain may also be performed, thus allowing the radar system to be flexible with respect to its environment. The lower bounds may also be applied to these estimates. Optimization of a radar system with respect to design parameters may then

be performed using the bounds. Of special interest is radar system performance against air targets near terrain.

General likelihood ratios for Gaussian clutter possessing some unknown, nonrandom parameters have been derived. A covariance function has been obtained of proper form for extraction of these parameters for a simple rough-surface model. A general estimation-detection scheme using these likelihood ratios has been formulated. Preliminary research has also been undertaken into normality of the clutter process.

Intrusion Detection and Identification. HDL conducted an optical field experiment at Yuma Proving Ground (YPG), AZ, in conjunction with the Lariat program. Lariat was a joint effort of the Combat Surveillance and Target Acquisition Laboratory (CSTAL) and the USAF Space and Missile Systems Organization (SAMSO) to assess how well ground surveillance can be arranged for overlapping coverage, to provide intrusion detection over a wide area. HDL investigated how well telescope/television systems can augment the surveillance function of the radars by providing a personnel-recognition capability. Specifically, the purpose of HDL's field experiment was to determine experimentally how far away people can be seen with passive optical systems under realistic desert conditions.

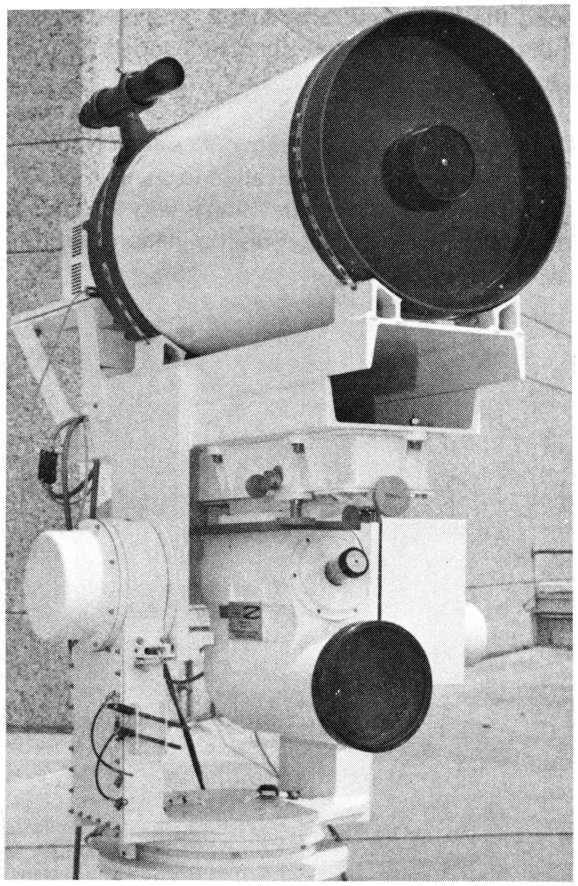

Figure 1. Intrusion detector.

The commercially available off-the-shelf equipment, assembled on short notice for the field experiment, consisted of a zoom telescope for target acquisition, a high-magnification telescope for identification, associated high-resolution daytime television cameras, low-light-level nighttime cameras, and an electromechanical azimuth/elevation mount to position the telescope/television system. Figure 1 shows the equipment, which was mounted on a 20-ft concrete tower at YPG. The zoom telescope is between the forks of the mount and the high-magnification telescope is on top. The accompanying control and television monitoring/recording equipment was housed in a test van at the base of the tower.

The system performed particularly well in daylight, even under scintillation conditions. Targets included walking and standing personnel, a horse and rider, jeeps, automobiles, and a pickup truck. Personnel could routinely be observed at ranges of 5 km or greater. Under moderate scintillation conditions with air temperatures above 100°F, personnel were seen walking at 13 km.

The system performed well with target hand-off from the radar. Because of its wide-area coverage, radar is well suited as the initial acquisition device. The optical system is then directed to look

around the perceived radar target. In every case, the optical system acquired targets handed off by the radar within 30 seconds.

HDL concluded that zoom optics are advantageous in tailoring the magnification to specific scintillation conditions. Color television is very effective in providing additional target-discrimination cues to help discern targets in foliage or against the bright horizon.

Once thermal viewers and millimeter radar systems are perfected, the ideal configuration for wide-area intrusion detection and identification would consist of a combination of television, radar, and thermal sensors.

devices and technology

Acousto-Optic Time-Integrating Correlator. A novel technique for implementing the acousto-optic time-integrating correlator has been discovered. It involves using surface-acoustic-wave (SAW) delay lines for the interaction medium. The two rf signals to be correlated are input at either end of the device using transducers tilted from the direction of propagation by θ_B (the Bragg angle). Two light beams (derived from the same laser) are focused on the side of the device to interact with the two counter-propagating SAW's. The angle between the two laser beams equals $2\theta_B$; this ensures that each laser beam will interact with only one acoustic wave. If this condition is met, the two first-order diffraction beams (at the device center frequency) will be collinear and will constructively add or destructively interfere depending on the phase and modulation of the two rf signals.

The output of an integrating diode array placed at the image plane of the acousto-optic device is thus proportional to the cross-correlation of the two rf signals. The time-bandwidth product, and hence the processing gain, of such a correlator can be very large as a result of the long integration time ($> 10^{-1}$ s) currently achievable. Such a system has been constructed at HDL and has an instantaneous bandwidth of 30 MHz and a processing gain of almost 60 dB. Broadband waveforms (e.g., pseudo-noise biphase-coded spread spectrum with a signal-to-noise ratio (S/N) of -20 dB) have been cross-correlated and detected. The top pictures in figure 1 (p 94) show the spectrum for a 5.0 Mbit/s pseudo-noise biphase-coded signal (centered at 200 MHz) at various S/N's, and the bottom pictures show the correlator output. The code rate and center frequency can be ascertained from the shape of the correlation peak. In addition, the displacement of the correlation peak from the center of the detector array is directly proportional to the time difference of arrival, and accuracies of 30 ns have been achieved.

Triple-Product Convolver. HDL is developing an acousto-optic implementation of the triple-product convolver (TPC). The TPC is an algorithm for performing an ultra-fast discrete Fourier transform (DFT). The many applications of this processor include real-time spectrum analysis of wide-band radar and communication signals, high-frequency direction finding, and frequency versus azimuth beamforming. The advantages of the acousto-optic implementation are the large bandwidths (> 500 MHz) achievable with SAW delay lines and the potential for achieving compact, lightweight devices using the rapidly maturing integrated optics technology. The program involves a feasibility demonstration of the TPC with multiple-input laser beams. The laser beams will be modulated with the information to be transformed by electro-optic KDP (potassium dihydrogen phosphate) modulators. The goal of the program is to have 32 lasers operating simultaneously at a modulation rate of 32 kHz. During the past year, an 8-laser input TPC has been put into operation that performs an 8-point DFT in about 60 μs. An example of such a transform of a rectangular pulse is shown in figure 2. The transform has the predicted form versus k of sin nk/sin k,

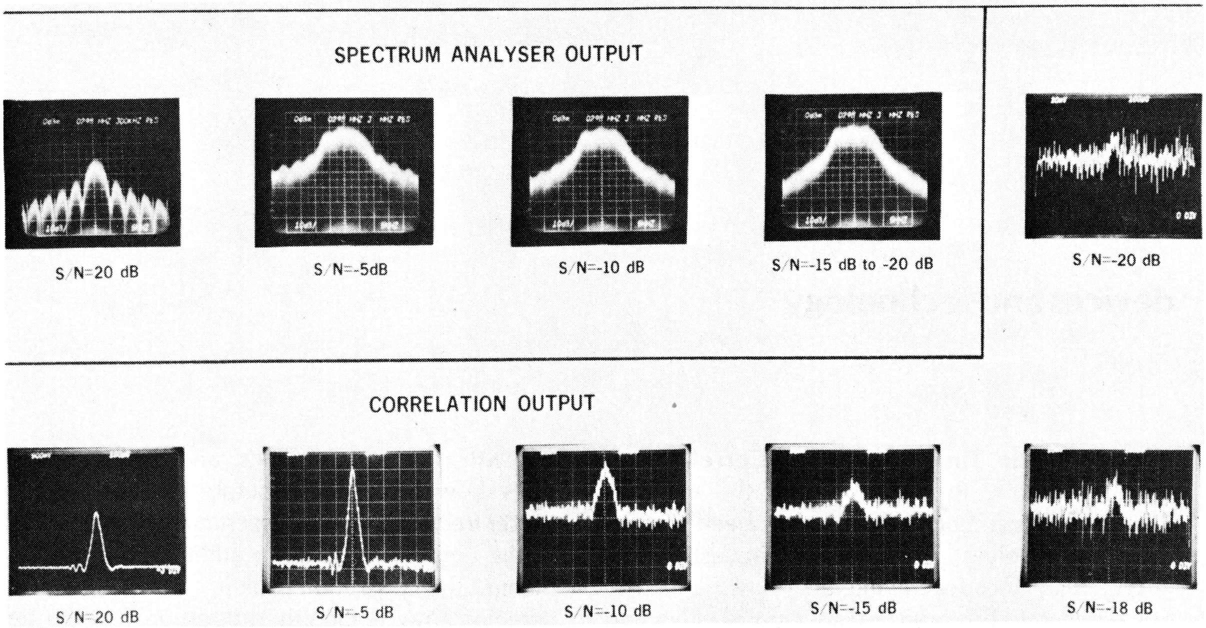

Figure 1. S/N enhancement of acousto-optic correlator.

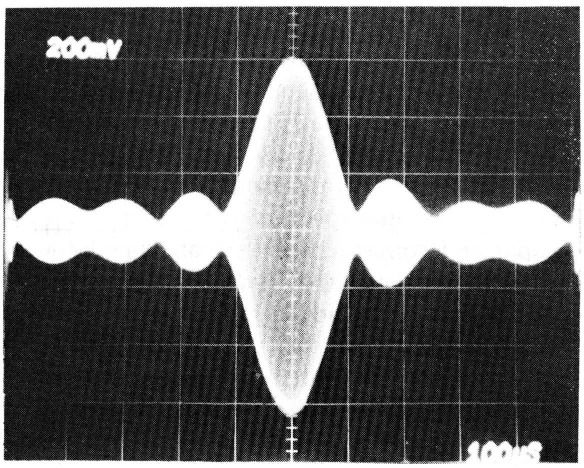

Figure 2. Eight-point discrete Fourier transform of rectangular pulse.

where n = 8. The 32-laser version is expected to become operational during FY80.

Acousto-Photorefractive Memory Correlator. A new memory effect has been discovered at HDL. The new effect consists of the coherent storage of rf signals in the form of charge patterns on the surface of lithium niobate. The charge patterns are formed as a result of a nonlinear interaction between propagating SAW's and very intense short-duration infrared (1060-nm) laser pulses. Figure 3(a) shows a scanning-electron-microscope photograph of the surface of the lithium niobate after an initial exposure. The black lines are an ordered pattern of electrons corresponding to the original SAW. Figure 3(b) is an enlargement. The charge pattern can be rapidly erased by either wiping with acetone or exposure to a plasma discharge. However, rewriting a new pattern after erasure requires an arrest of either time (more than one day) or high temperature (> 250°C). Attempts to rewrite without such procedures yield incomplete charge patterns, as shown in figures 3(c) and 3(d). Work is proceeding in developing a physical model for the newly discovered phenomenon, as well as in optimizing the effect. A direct application is for an acousto-optic memory correlator where the stored charge pattern produces an index-of-refraction variation that can be sensed by a low-intensity laser beam and used as a reference for the identification of unknown rf signals. Such an acousto-optic correlator using the stored patterns has been constructed and Barker codes up to order seven have been successfully identified.

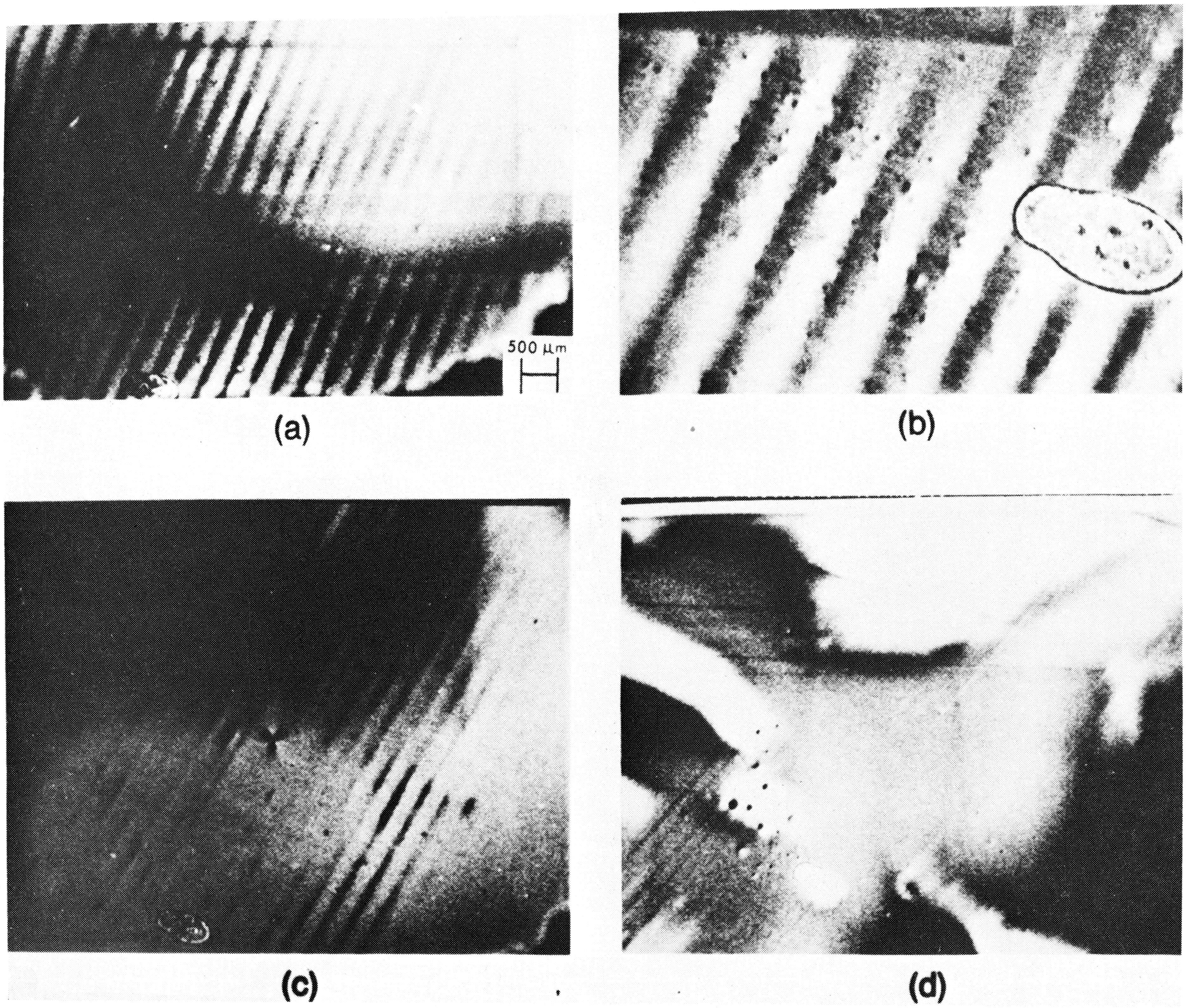

Figure 3. Scanning electron micrographs of stored charge on surface of $LiNbO_3$.

electro-optics

Laser Heterodyne Detection. HDL is investigating the potential of using infrared heterodyne detection in active fuzing and other target-sensing applications. The potential advantages include increased detection sensitivity, the availability of Doppler information, and possibly increased aerosol immunity. Two central problems are being addressed. One concerns the estimation of the heterodyne signal in the typical fuzing encounter, where the target surface has roughness on the scale of the illuminating laser's wavelength, and where target and receiver are in near-field proximity. The other is to develop a coherence-theoretic characterization of the reflecting target surface that is both amenable to experimental determination and suitable for determining the heterodyne signal.

The combined effect of target surface roughness and the relative closeness of target and receiver in the fuzing application results in complicated equal-phase and equal-amplitude signal-field surfaces at the receiver aperture. To analyze and predict the heterodyne signal in such cases requires the use of partial coherence theory. Last year, the coherence-theoretic methods needed for the analysis were developed, and substantial progress was made on computer codes to perform the complex integral propagator calculations indicated by the analysis.

It was determined last year that the boundary values of the reflected field's cross-spectral density function (a frequency-dependent function describing the spatial coherence of the field) over the illuminated target surface are sufficient for the calculation of the heterodyne signal, and it was proved that such data can in principle be determined from measurements of the far-field intensity pattern produced by the reflector.[1] Such measurements were performed last year for surfaces exhibiting a gauged range of roughness, using a highly coherent CO_2 laser. In addition, a heterodyne system was built around a pair of CO_2 lasers and a cooled HgCdTe photovoltaic detector for making heterodyne signal measurements on the same surfaces, so that signal measurements and signal calculations could ultimately be compared.

This year, novel computer codes for the performance of the complex calculations leading to the heterodyne signal were developed.[2-3] This work was very successful, for the codes accomplished these lengthy calculations about 100 times faster than the heretofore best known techniques. The calculations can now be done at reasonable cost and in reasonable time.

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[1] *D. McGuire, Source Coherence and Far-Field Intensity Patterns, Opt. Comm., 29, 1 (1979).*

[2] *T. Hopp, IFEIX: A Routine for the Numerical Evaluation of Integrals with Oscillating Integrands, presented at the 1979 Army Numerical Analysis and Computer Conference.*

[3] *T. Hopp, QUINTEG—A Program for Computing Gaussian Quadrature Coefficients, Harry Diamond Laboratories, HDL-TR-1890 (August 1979)*

The far-field intensity measurements were completed,[4] and the preliminary heterodyne signal measurements were performed on a number of surfaces. Some additional heterodyne signal experiments will be needed before comparison with the signal calculations can be made.

Substantial progress was made on the problem of determining the needed boundary values of the reflected field's cross-spectral density function from far-field intensity patterns. This entailed developing a mathematical solution to an unsolved inverse source problem, and applying the solution to the boundary value determination problem. A scheme for making the determination was worked out, but a study of error propagation is still needed.

A rough approximate approach to the foregoing problem was also developed, and then applied to an example of measured far-field intensity data. The target-boundary values thus obtained, in conjunction with estimates based on computer code results, indicated that the surface in question would produce a nearly optimum heterodyne signal if encountered at normal incidence. On the other hand, computer code results using different, but theoretically plausible, target-boundary values indicated a normal incidence heterodyne signal on the order of hundredths of the optimum signal. Further calculations and a final report discussing all results will conclude the project next year.

[4]*L. Larson, Reflectance Properties of Selected Surfaces in the Far Infrared, Proc. 19th Annual Student Technical Symposium, Harry Diamond Laboratories (1978).*

penetration of obscurants

Near-Millimeter-Wave Technology. Military systems must be designed to be fully operational in adverse environments such as naturally occurring fog, clouds, rain, and snow, as well as battlefield-induced conditions such as dust and smoke. HDL is developing a near-millimeter-wave (NMMW) technology base that will allow the design of systems to meet these requirements. The NMMW portion of the spectrum (100 to 1000 GHz) offers an attractive compromise between the low-loss propagation characteristics of microwaves and the higher resolution capabilities of infrared devices. During FY79 the HDL research program addressed several areas where there are critical technology gaps. One part of the program included investigation of new improved NMMW sources, detectors, and antennas. Another part of the program was directed toward the acquisition of a data base on target and clutter/background signatures that is needed for NMMW system design.

Diffraction Electronics. A program was initiated this year to design and construct a relatively new type of electron-beam device, called an orotron, that generates coherent electromagnetic radiation in the NMMW range. The program was begun to investigate the characteristics of orotrons operating in various wavelength regions of interest to the Army's NMMW program and to determine experimentally, as well as theoretically, optimum parameters and designs that will yield efficient, tunable orotron-type NMMW devices. The first experimental orotron was designed to operate in the 4-mm wavelength region.

The principle of operation of the orotron is based on the Smith-Purcell effect. The device consists of an electron-beam generator and collector and a Fabry-Perot resonator containing one grooved mirror (grating) and one smooth mirror. This device is operated by passing a thin ribbon beam of electrons over, but not touching, the surface of the conducting diffraction grating. The electronic field associated with the beam is diffracted by the grating, resulting in radiation. This radiation is fed back onto the electron beam by the open resonator and causes the beam to bunch. As the device operates, some of the radiation is directed through or past the upper mirror, providing a useful output.

The HDL-designed electron gun required for the experiments has been built and delivered. This gun produces a 10×0.3 mm ribbon beam with a current density of about 5 A/cm^2 and an accelerating voltage of 2500 V. Theoretical and experimental work was done to assure that a relatively uniform magnetic field would guide the beam. Calculations were performed at HDL showing that the transconductance of the device, $\Delta f/\Delta V$, would be about 0.3 MHz/V; this calculation facilitated our determination of the electron-gun power-supply requirements. Grating parameters were also calculated and several gratings were made accordingly by the HDL shop. In addition, the orotron housing and resonator were designed and built. Testing, experimental work, and future designs are to continue into FY80.

NMMW Gyrotron. One of the most promising high-power NMMW sources, at present, is the cyclotron resonance maser, also known as the gyrotron. The attractiveness of this tube is due both to the theoretically high efficiency predicted for it and to the remarkable performance of such tubes built by the Soviets. Examples of this performance are 1500 W cw at 9.9 mm and 1.1 MW pulsed power at 3 mm with efficiencies around 10 percent.

In a joint effort by HDL and the Naval Research Laboratory, a gyrotron oscillator, or gyromonotron, is being built which is expected to have an output power at 240 GHz of about 3.5 kW with an overall efficiency of 13 percent. Figure 1 is a schematic of the overall layout of the device. Major components of the gyrotron oscillator are either completed or being fabricated. The highly uniform axial magnetic field required for the cyclotron resonance maser interaction is to be produced by a super-conducting magnet system. Since the maximum magnetic field produced by this magnet is 60 kG, the minimum possible cyclotron harmonic, namely the second, was chosen. The magnetic field in the central region has been found to be uniform to at least 0.25 percent by Hall-probe measurements. Such uniformity is required for optimum gyrotron efficiency. The 30-kV, 1-A magnetron-injection electron gun and power supply/modulator systems have been designed and are being fabricated under contract. Ka band measurements are in progress on large overmoded cavities near the cutoff of the TE_{051} mode. The results of the measurements will indicate the preferred configuration for the 240-GHz cavity which must have an overall Q of about 5000, including output coupling. Cold testing of the 240-GHz cavities and output circuit will be performed when Y-band sources, detectors, and waveguide hardware, now on order, arrive.

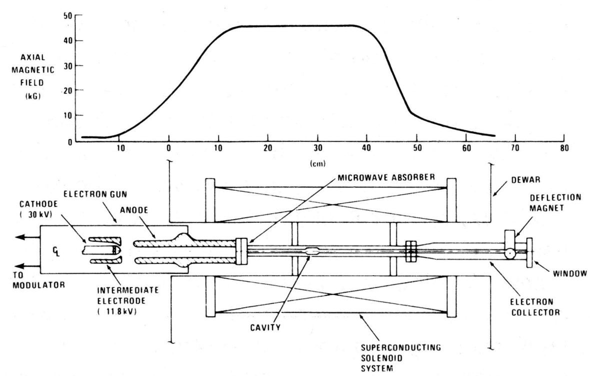

Figure 1. Schematic of gyrotron oscillator and plot of axial magnetic field.

NMMW Solid-State Sources. Research begun last year on optical control of pulsed IMPATT diodes was continued. Silicon double-drift IMPATT diodes in a waveguide-configured oscillator circuit were illuminated by infrared radiation from a pulsed GaAs laser diode. The objectives of these investigations are to (a) eliminate the leading edge jitter of the pulse, (b) eliminate in-pulse chirp, (c) obtain frequency locking for coherent pulse sources, and (d) derive modulation schemes of the IMPATT oscillator via laser modulation and/or parametric (subharmonic) injection in the bias circuit for frequency stabilization. Laser irradiation of a millimeter-wave IMPATT resulted in two modes of operation: the enhancement mode and the inhibition mode. The IMPATT diode oscillator used for these experiments generates about 500 mW of pulse power at 72 GHz, with a duty factor of 0.5 percent. It was found that the injected laser power into the junction has to satisfy a threshold condition for the inhibition mode. Pulse waveforms of the inhibition mode had excellent rise time and jitter characteristics. Techniques for measuring noise and jitter in association with the injection experiments are being developed. IMPATT oscillators operating at 94 and 140 GHz have been ordered, and investigations of optical control of these devices are planned. A contract has been awarded to the University of Michigan by ARO for analytical work in support of HDL's experimental work on NMMW solid-state sources.

Optically Pumped NMMW Sources. Basic research has continued at HDL to develop new highly coherent NMMW laser sources. Typically these sources consist of an NMMW resonator filled with a gaseous media that is pumped with radiation from an infrared laser (for example, a CO_2 laser). These sources generally have narrow bandwidth, low broadband and background noise, high collimation, and potential for very high, long-term frequency

stability. This year, research concentrated on the generation of high peak power at specific frequencies and on a search for new laser lines for reference standards. The latter effort is strongly coupled with the HDL effort on ultra-high-resolution spectroscopy of NMMW laser gases.

The search for new NMMW laser lines is conducted using a waveguide resonator and a CO_2 infrared laser pump. Achievements this year include the discovery of three new optically pumped sources containing the gases deuterated methyl fluoride, ethyl iodide, and chlorodifluoromethane. In all, 16 new NMMW laser lines ranging from 0.16 to 1.48 mm have been found. Another aspect of the program has been aimed at increasing the efficiency of these sources at the longer wavelengths (greater than 0.5 mm) through improved resonator design. A Michelson output coupler has been designed to provide variable output coupling from an oversized metal waveguide resonator. A one-dimensional wire-grid beamsplitter has been employed for the first time in this type of output coupler. Initial results show good mode selectivity, linearly polarized output, and several milliwatts of cw power at 1.22 mm, using isotopic C^{13} methyl fluoride.

High-peak-power pulsed optically pumped NMMW laser sources were studied using unstable resonators. These resonators are many times more compact in length than more conventional waveguide resonators of the same volume, while providing similar coherence and power. Outputs of 5 and 1 kW were obtained at 604 and 246 GHz, respectively, with a 50-cm-long resonator. Competing fluorescence-like and Raman-like processes were studied on a nanosecond time scale.

Ultra-High-Resolution Spectroscopy. This year research continued on the spectroscopy of gases for use in optically pumped NMMW lasers. Novel ultra-high-resolution spectroscopic techniques have been developed that permit Doppler-limited resolution of molecular absorption lines which are important in the stimulated emission process. The lead-salt laser diode heterodyne spectrometer has been refined to yield rapid and routine measurement of infrared absorptions lying within ± 6.5 GHz of a CO_2 laser emission line to better than 10 MHz (0.00033 cm^{-1}) precision and accuracy.

Figure 2 is a schematic diagram of the diode laser heterodyne spectrometer. The infrared radiation from the diode laser was divided into two paths by a beamsplitter. One portion of the diode-laser radiation passed through a gas absorption cell and was directed to an HgCdTe detector operating in the video mode; the other portion was sent to an SAT Model C4 HgCdTe photomixer and heterodyned with CO_2 laser radiation. Beat signals were amplified by low-noise, wide-band amplifiers and were detected by a well-calibrated spectrum analyzer operating as a narrow-band (~100-kHz) receiver. An 80-Hz sawtooth current ramp was applied to tune the diode laser. A dual-trace oscilloscope was used to display the temporal coincidence of the video absorption and the marker pip from the spectrum analyzer; this technique is similar to that used in microwave spectrometers.

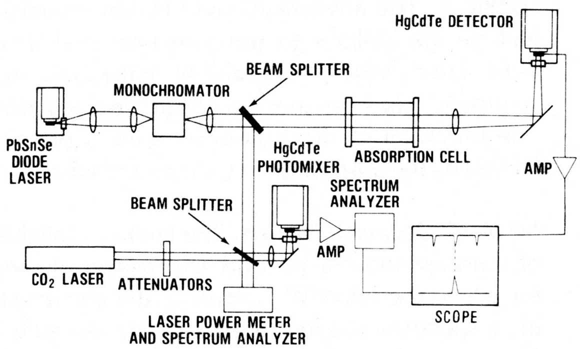

Figure 2. Schematic of ultra-high-resolution diode laser heterodyne spectrometer for analysis of NMMW laser gases.

The gas 1,1-difluoroethylene is of interest as a photon-pumped submillimeter-wave source. More than 400 infrared absorption lines have been measured in this gas by the above technique. Preliminary fitting of these lines to Watson Hamiltonians yields improved molecular constants, and shows a standard deviation less than 6 MHz. Figure 3 is a dual-trace chart recording of the molecular spectrum and heterodyne markers at plus and minus

4500 MHz from the 10P(22) CO_2 laser line. Quantum numbers have been assigned for almost every spectral line in the trace.

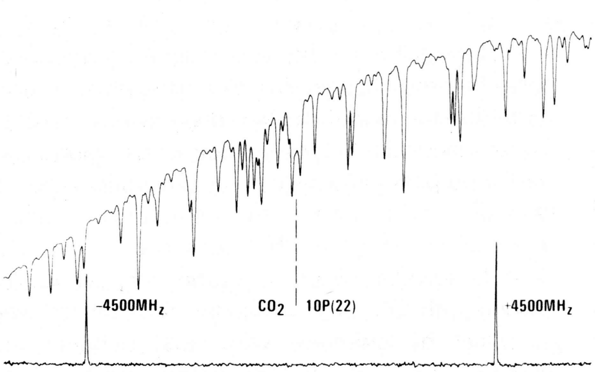

Figure 3. Dual trace chart recordings of ultra-high-resolution absorption spectrum of 1,1-difluoroethylene gas and heterodyne markers at $\pm$4500 MHz from the IOP(22) CO_2 laser line.

The accuracy of the technique has been confirmed by heterodyne measurements of CO_2 absorptions. The advantages over etalon techniques include the abilities to measure near and across diode-laser mode breaks, and to make rapid measurements free from thermal and geometrical drifts. The precision of the instrumentation is presently limited by the absorption line shape and width.

NMMW Detector Mixers. The limited availability of sensitive and practical detector/mixer elements for use in the NMMW portion of the electromagnetic spectrum has led to exploratory research for alternative materials. The investigation has centered on photoconductors, whose characteristic ruggedness, ease of fabrication, and reproducibility have made them useful for infrared imaging systems. Recently, HDL reported on the first observation of hot-electron photoconductivity in the alloy semiconductor mercury cadmium telluride ([Hg,Cd]Te). A change in photoconductivity due to the absorption of NMMW radiation of free-conduction-band electrons has been detected in 10-μm band-gap, n-type material cooled to about 4 K. Klystrons, backward-wave oscillators, and optically pumped lasers were used to characterize the detector at wavelengths between 100 and 400 μm. Peak sensitivity is comparable to that observed for hot-electron photoconductivity in n-type InSb. At short wavelengths, the relative response of the [Hg,Cd]Te detector was found to increase approximately as the wavelength squared, reaching a maximum at about 1000 μm and then remaining constant out to at least 4000 μm. Preliminary results indicate a detector noise-equivalent power, NEP, of less than 1.2×10^{-10} W/$\sqrt{\text{Hz}}$ with a bandwidth of about 1.2 MHz. In addition, a linear sensitivity to input radiation power of over three orders of magnitude has been measured.

NMMW Antennas. The link between NMMW system hardware and the battlefield is an antenna that radiates or collects energy in the sector of interest. In order to insure the availability of NMMW antennas that perform the required beam shaping and scanning operations, HDL has initiated an in-house program to (1) establish a technology base, (2) develop a test and evaluation capability, and (3) investigate antenna designs for use in NMMW systems.

Recent accomplishments include fabrication of an indoor far-field pattern range for testing antenna elements and small arrays, establishment of a compact antenna range for testing moderate-sized antennas operating in the 85 to 105 GHz frequency region, and fabrication and testing of several dielectric rod antennas and slotted waveguide arrays. Some examples of these antennas are shown in figure 4. Test results indicate that the slotted waveguide antennas can be designed and fabricated to meet a variety of system needs.

NMMW Measurement Standards. Both research and system development in the NMMW area are being seriously hampered by a lack of basic measurement standards. This is especially so for frequencies above 100 GHz. A program was initiated this year at HDL for the development of techniques to accurately measure quantities such as frequency, power, and cavity Q in the NMMW spectral region. One of the measurement techniques that is being developed in this program is an NMMW heterodyne spectrum analyzer for use at around 240 GHz. The signal from a source under test (for

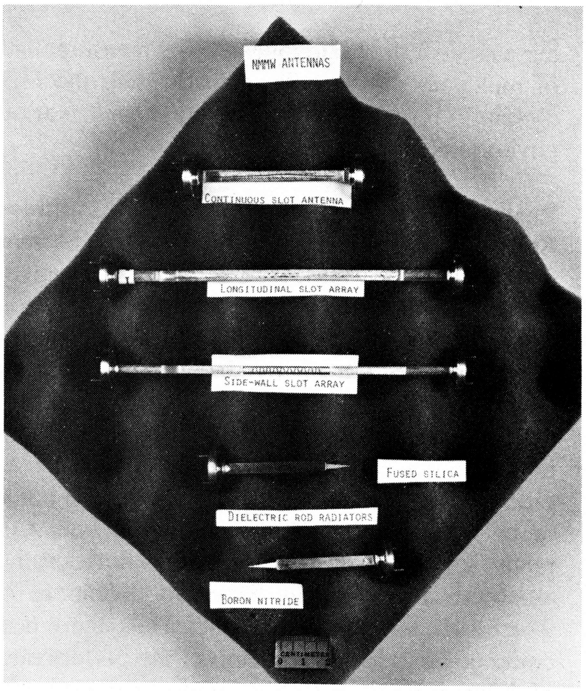

Figure 4. Several dielectric rod and slotted waveguide antennas fabricated for operation in the 85 to 105 GHz frequency range.

example, a 240-GHz gyrotron) will be combined and mixed with a stable 240-GHz local-oscillator signal. The approximately 2-GHz wide IF signal from the mixer is then analyzed with a standard commercial spectrum analyzer. The local-oscillator signal will be obtained by frequency doubling the output of a 120-GHz klystron with a varactor diode doubler having an output-to-input efficiency of 5 percent and a bandwidth of 2 GHz. About 5 mW of power should be obtained in this manner. Accurate measurements of frequency in the NMMW region are required, especially for cavity Q measurements and examination of coherent properties of experimental NMMW sources. Since the Q's of commercially available wavemeters in this region have a value of, at best, 5000, other approaches, such as wavemeters based on confocal Fabry-Perot interferometers, are being pursued.

NMMW Mobile Measurement Facility. Basic information on target and clutter/background signatures, as well as atmospheric transmission, is either lacking or incomplete for the NMMW frequency range. To provide the data base necessary for NMMW system design, a mobile measurement facility (MMF) is being developed by HDL. The facility is being designed and constructed by the Engineering Experiment Station of the Georgia Institute of Technology under contract with HDL. When complete, this facility will be capable of measuring reflections from targets, backscatter from rain and other hydrometeors, background clutter, and attenuation in environments that contain fog, rain, snow, dust, smoke, chaff, or foliage, or combinations of these.

The MMF will be equipped to make simultaneous measurements at frequencies of 94, 140, and 220 GHz. In addition, meteorological measurements to characterize the environment will be made concurrently with a separate facility being constructed by the Atmospheric Sciences Laboratory. A block diagram of the NMMW/MMF is shown in figure 5.

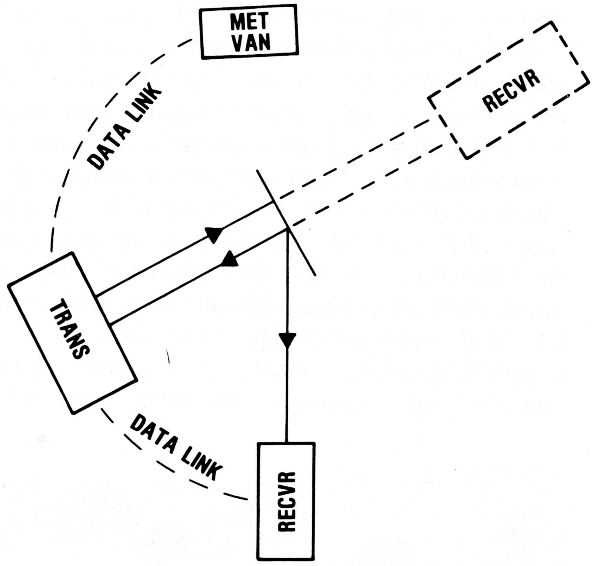

Figure 5. Schematic showing positioning of HDL NMMW mobile measurement facility vans and ASL meteorological measurement van for measurement of target reflection (dotted lines show position of receiver van for transmission measurement).

During this year, design of the NMMW/MMF was completed and construction is well under way. The trailers have been refurbished; heating and air

conditioning units have been checked and repaired, as have the main power generators. The minicomputer, the NMMW hardware, and all other equipment that requires a long lead time for delivery have been ordered; the design of the data-acquisition electronics has been completed and construction is progressing. When it becomes operational in October 1980, the mobile measurement facility will be available for Army-wide use anywhere in the world.

Multipath Measurements. NMMW components have size and weight advantages over their lower frequency counterparts that will allow tactical radar systems to be designed for high-mobility and quick-reaction-time applications. For proper interpretation of NMMW radar returns for the detection and tracking of ground targets, the contribution of multipath signals to the return must be known. During the past year HDL began a program to measure and characterize multipath signals to determine their effects on the performance of ground-based NMMW tactical radars. As a first step in this program, an elementary cw 94-GHz transmitter and receiver were constructed and measurements were begun. Figure 6 is a close-up photograph of the all solid-state system. Gunn oscillators were used for both the transmitter and local oscillator. An IF signal centered at 1.5 GHz is produced at the output of the balanced mixer. The system has an IF gain of about 50 dB with a bandwidth of 1 GHz. At present the signal returns are displayed and measured with a calibrated spectrum analyzer. The system will be upgraded and extensive measurements made during next year. In the following years measurements of multipath effects will be made with the HDL mobile measurement facility in various environments.

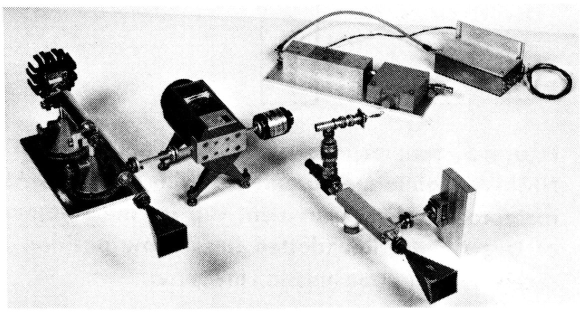

Figure 6. 94-GHz transmitter and receiver for measurement of multipath effects.

Realistic Battlefield Environmental Conditions. At the request of the Director of Battlefield Systems Integration, DARCOM, HDL conducted a study to assess Army operations under limited-visibility conditions. Operational standards for environmental conditions are needed by developers, modelers, and those who evaluate the performance capabilities of weapons under nonideal environmental conditions. Such conditions can occur naturally, be produced unintentionally in the course of a battle, or be induced by deliberate enemy action. Currently, such operational standards do not exist, nor are there any generally accepted definitions by which such standards can be set. Thus, there is no common basis for comparison of the performance of different types of systems under realistic battlefield environmental conditions.

The HDL study sponsored by the Director of Battlefield Systems Integration is intended to develop concepts leading to standard conditions for electro-optic (EO) devices. The Atmospheric Sciences Laboratory has supported this effort by providing climatic data, and the Night Vision and Electro-Optics Laboratory has supported the effort in the target signatures area. A first step towards providing a set of definitions for such standards is presented in a draft report which has been distributed within DARCOM for comment. This report provides the background and rationale for this effort, as well as some limited data on battlefield environmental conditions. Definitions are suggested in the areas of natural, battlefield-induced, and enemy-induced environments. It is shown that data on these environmental factors can be reduced and presented in a format equivalent to that currently used in existing standards documents for physical survivability. Data on natural environmental factors affecting EO link reliability and target signatures are analyzed. Comments received and modifications suggested are being incorporated into the report, which will then be published in final form, completing the HDL effort on this task.

Optical Characterization of Smoke and Dust. In November 1978, HDL made aerosol characterization measurements during Smoke Week II at Eglin AFB, FL. Various inventory and developmental US smokes, foreign smokes, HE-created dust, and vehicular dust clouds were generated at this two-week-long Army-wide test run by DARCOM's Project Manager Smoke/Obscurants. In addition, the early-rising HDL team managed to obtain data in a very dense morning fog. The same HDL equipment that is normally flown as part of the program on aerosol discrimination for optical fuzing (described under *Fuzing—Exploratory Development*) was mounted in a large box in the middle of the area where the aerosol was expected to be (and usually was) carried by the wind. Figure 7 shows the HDL box at the site, along with Dugway Proving Ground aerosol sampling and meteorological equipment. For these tests, the configuration of the laser probe was modified to yield aerosol characterization data, an effort partially sponsored by TECOM. The objective was to determine whether the laser probe could provide nephelometer-like smoke and dust characterization but with finer spatial resolution. The preliminary results, which are encouraging, were reported at the third Smoke Symposium, held at HDL in April.[1]

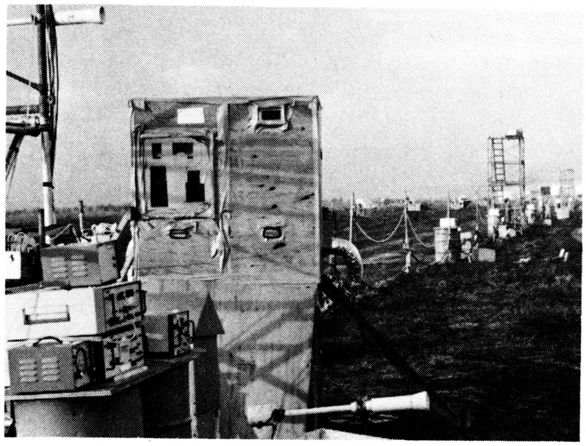

Figure 7. HDL instrumentation at Smoke Week II (in box).

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[1]*Z. G. Sztankay, J. Nemarich, J. Griffin, W. Hattery, and G. Wetzel, Backscatter and Extinction Measurements at Smoke Week 2, Proceedings of Smoke Symposium III (1979).*

electronic warfare

Anti-Radiation Missile Countermeasures (ARM-CM). The objective of the ARM-CM program is to develop effective means of reducing the vulnerability of Army ground-based and airborne emitters (such as radars, communication systems, and so on) to attack by enemy ARM systems. The major areas of effort or program dimensions are

- use of intelligence to model and simulate threat,
- evaluation of CM technology,
- development of CM technology and techniques,
- exploitation of ARM seeker technology,
- evaluation of the interaction of tactics, scenario, and CM techniques, and
- evaluation of ARM-CM data and dissemination to the tri-service community.

One of the principal tools used in the evaluation of ARM-CM technology and techniques is digital simulation. The central role of simulation is shown in figure 1, which also illustrates the flow and interdependence of information developed in the different parts of the program. Evaluation of intelligence and comparison with US ARM technology provide data for generating models of threat ARM's which, along with models of emitters and CM design, are used in the simulations to evaluate the effectiveness of the CM. Field testing is used to obtain data in a realistic environment to validate the modeling of the ARM, emitter, and CM. This evaluation process is an iterative one, whose output will be used in recommending new or refined prototype CM designs or techniques. Complete evaluation of a CM should also include an assessment of the tactical and logistical burden it imposes on the protected system or on neighboring systems. Hence, as indicated in figure 1, the "Tactical Scenario Impact" is also studied.

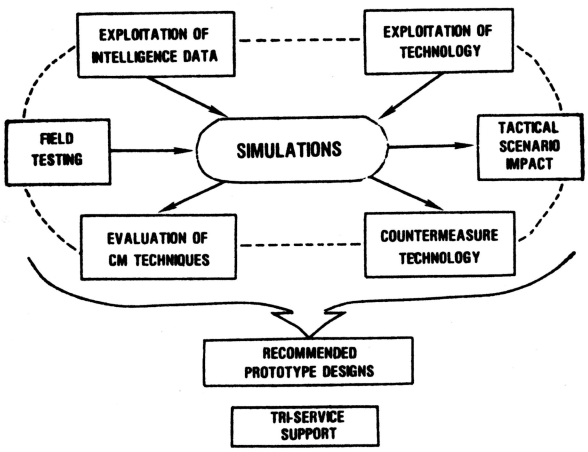

Figure 1. Flow of information in ARM-CM program.

The ARM-CM program also supports the individual Program Manager's Offices (PMO's) in the development and evaluation of ARM-CM's specific to their systems. In addition, as the lead service, the

Army program supports the tri-service community by the dissemination of data via the Joint Working Group (JWG), and by the development of simulations and field-test instrumentation for tri-service use.

HDL also provides the chairman for the tri-service ARM-CM JWG, which was formed at the direction of the Office of the Undersecretary of Defense for Research and Engineering. The JWG's objective is to define the present and projected ARM threat, identify ongoing ARM-CM programs within the services, and initiate a nonduplicative program which could proceed on a tri-service basis.

Anti-Radiation Projectile Sensor. The sensor for the Anti-Radiation Projectile (ARP) began advanced development at HDL in February 1979. The ARP is the initial Army configuration of the 8-in., extended-range guided projectile (ERGP). The ERGP, with the Army's ARP sensor and a US Marine Corps Semi-Active Laser sensor, is being developed by the Office of the Project Manager for Cannon Artillery Weapon Systems (PM-CAWS), Dover, NJ, which is also the DoD Joint Project Office for Guided Projectiles. The Advanced Development program will be performed in-house with major participation by both Army and Navy Laboratories. HDL is responsible for the anti-radiation sensor that will allow the ARP to home on targets that emit rf energy within its frequency coverage. Functionally, the sensor includes the rf receiver and direction-finding system, as well as the analog and digital circuitry required to detect and sort targets and produce a signal that tells the projectile's autopilot where the target is relative to the axis of the projectile. The Naval Weapons Center (NWC), at China Lake, CA, has been funded by HDL for the lead role in the initial design of the ARP sensor. This insures that full advantage will be taken of the extensive experience in anti-radiation sensors at NWC acquired during the Navy's development of anti-radiation missiles such as Shrike and Harm. HDL is also funding Lincoln Laboratories for some work to extend the ARP sensor capability.

signals warfare

Artillery - Delivered Unattended / Expendable Communication Jammer. The advanced development program for the Unattended/Expendable Jammer (UEJ) was initiated at HDL by the Signals Warfare Laboratory (SWL) in June 1978. The purpose of the program is to design, develop, and ultimately field-qualify a low-cost, gun-rugged expendable communication jammer. The UEJ delivery is similar in concept to the M718/M741 Remote Anti-Armor Mine System (RAAM), shown in figure 1, which includes nine individual mines loaded within a single M483 cargo projectile. The jammer is to be packaged for deployment by the same 155-mm weapon system, to make maximum use of the existing technology built around the RAAM system.

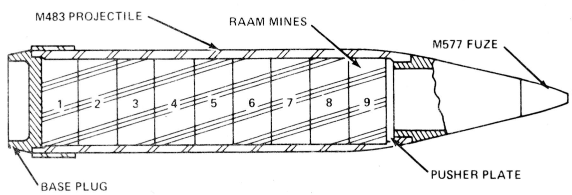

Figure 1. Artillery-delivered RAAM system configuration.

The UEJ is a barrage communication jammer designed to operate in the lower vhf range. When deployed beyond the forward edge of the battle area, the jammer will disrupt and confuse enemy tactical communications without affecting those of friendly forces.

The components within the UEJ package are a reserve power supply, transmitter, timer, antenna, and ground radials. A reserve as opposed to an active power supply must be used because of a 10 to 20 year storage requirement. This type of power supply will permit the jammer to be stored for long periods of time with no degradation in power capability. The timer is needed to initiate UEJ ejection from the M483 projectile in flight and to release the antenna/ground radials and turn on the transmitter following impact on the ground.

During FY79, the major effort was directed toward the higher risk areas of the UEJ design. These areas included the power supply, antenna, and dispersion technique. The dispersion technique currently being developed is one-at-a-time linear ejection, in which each jammer is ejected from the M483 at a predetermined time interval. The resultant pattern is a line of jammers on the ground spaced a distance apart equivalent to the timer interval. Each M483 projectile contains six jammers. The UEJ package will use fins, as shown in figure 2, to decrease the velocity of the package following ejection and to orient the jammer so that it lands upright. Once the jammer lands and the timer explosively removes the cover plate, the antenna and ground radials are released as shown in figure 3. Shortly after the antenna and ground radials are released, the transmitter is turned on.

In the early part of FY80, a Critical Design Review is planned. At this review, the advanced development baseline design will be selected. Until that time, HDL will continue to investigate and test various designs for each part of the jammer system.

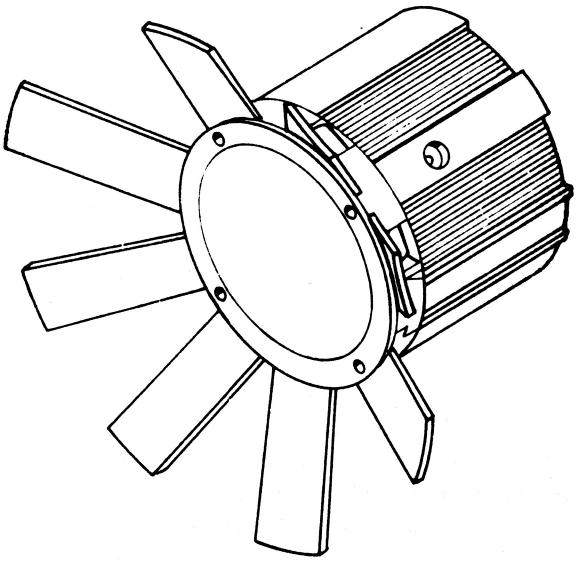

Figure 2. UEJ package with side-mounted vanes.

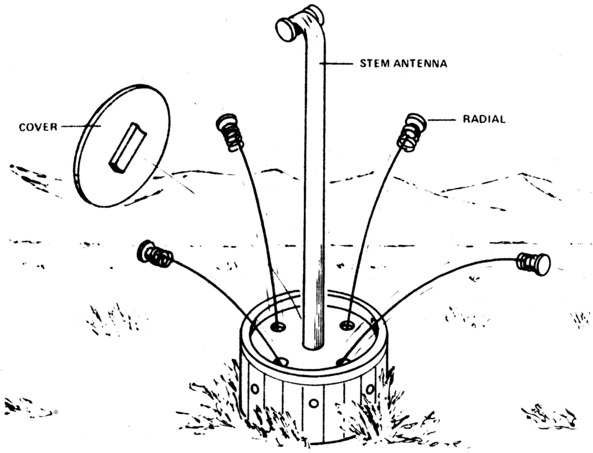

Figure 3. UEJ antenna and radials in deployment.

general support

Copperhead Operational Test Instrumentation. HDL had previously designed and fabricated four sets of electro-optical instrumentation for the Operational Test and Evaluation Agency (OTEA) to support the operational test (OT) of the Ground Located Laser Designator (GLLD). These instrumentation systems were refurbished and modified by HDL in coordination with the Naval Weapons Center (NWC), China Lake, to support the Copperhead OT. Modifications to these systems included (1) altering the pulse-ranging circuits and software to generate range-sorted information, (2) hardening the cameras and digital recorders used in the system to the field environment, and (3) adjusting camera brackets to the new GLLD nightsight mounts.

HDL provided NWC with technical assistance, training, and documentation to facilitate their support of the Copperhead tests. The modified systems were delivered to NWC on schedule. Equipment interface and personnel instruction were performed at NWC before equipment delivery to Ft. Carson. This instrumentation performed well throughout the Copperhead test and is now considered required instrumentation for several upcoming major Army and Navy tests.

ITV Test Instrumentation. HDL had designed and fabricated electro-optical instrumentation for OTEA in support of the OT for the Improved TOW Vehicle (ITV). This instrumentation has been used in all previous ITV OT's. HDL refurbished five sets of instrumentation, coordinated laser loan and support with MIRADCOM, and performed all necessary field maintenance during the two-month OT. Documentation and personnel training were also provided for support of this test. The instrumentation systems were delivered on time and the prerequisite maintenance and support provided in the field.

Support to Laser Terminal Homing Programs. HDL continued its support to the Army's Laser Terminal Homing programs in FY79. This support took two forms: (1) staff support to the Copperhead, Hellfire, and Laser Designator Project Offices in counter-countermeasures (CCM) and coding and (2) design and fabrication of a prototype countermeasures-hardened coding system for the Hellfire project. These efforts were a continuation of the CCM support that HDL has provided to laser terminal homing programs since 1970.

Staff support to the project offices included inputs to the Copperhead Cost and Operational Effectiveness Analysis, review of Copperhead and Laser Designator test plans, review of Copperhead specifications relating to US and NATO interoperability, and participation in meetings and reviews relating to CCM policy for all three Army systems.

The prototype coding system fabricated for the Hellfire system is a feasibility model of the "R Code" conceived and partially designed in FY78.[1] The missile decoder, laser designator encoder, and

[1] *James S. Shreve, The Laser-Guided-Hellfire R Code (U), Harry Diamond Laboratories, HDL-SR-78-4 (November 1978). (CONFIDENTIAL)*

attack helicopter avionics package were fabricated and laboratory tested. The tests confirmed the performance predicted in the earlier design study. Field tests at Blossom Point demonstrated proper operation of the system at realistic designator-to-target-to-missile ranges. The system was delivered to the Office of Missile Electronic Warfare in late September and will be tested there in FY80. A final report will be published by HDL in FY80.[2]

Tank-Appended Crew-Evaluation Device (TACED). The 1978 edition of this report described the TACED. This device provides a videotape recording and a real-time TV presentation of the gunner's (M32 periscope or M10SC telescope) view in the M60 A1 tank.

HDL completed the design and fabrication of two TACED prototypes early in 1979. The Armor Center at Ft. Knox performed extensive testing[3] of these prototypes during April 1979. The TACED met all design goals; all components of the device withstood the tank environment, except for the videotape recorders. The Armor Center is preparing a test report. PM TRADE, the sponsor for this activity, will decide on further development upon receipt of this report.

Hard-Structure Munition (HSM) Power Supply. An air-driven fluidic-generator power supply is being successfully developed for the hard-structure munition (HSM) bomb, wherein a pair of generators is employed. The aircraft-released laser-guided bomb (see fig. 1) is designed to penetrate hard-structure targets such as reinforced concrete bunkers, bridge footings, and silos.

The fluidic generators for HSM are designed to provide (1) safe arming separation distance from aircraft and (2) arming energy for the fuze electronics and firing train. When the bomb is released from the aircraft, two air-intake housings mounted on the bomb surface pop up and allow ram air to enter their respective generators. The generators convert ram air into electrical output. The generator operates at velocities up to 550 m/s and produces a maximum power of 10 W. Preliminary flight drop tests indicate successful functions of the generator.

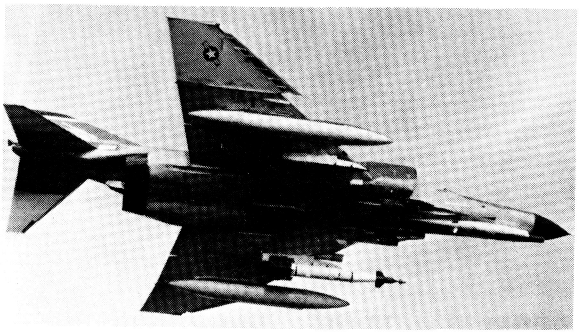

Figure 1. Hard-structure munition bomb with fluidic generator power supply.

G-76( )/G dc Generator. In support of the PM Army Tactical Communication System (ATACS) a hand-cranked power source was designed to power remotely operated field radios and recharge batteries. It has progressed through an accelerated development cycle to the point where it is now undergoing DT/OT-II tests which are expected to be completed in October 1979. A DEVA-IPR is scheduled for January 1980. A production contract is expected to be placed by July 1980.

The G-76, which weighs 13.4 lb, has two separate outputs. One of them provides from 0 to 30 V, with the voltage regulated to cut off at 30 V, and the actual voltage depending upon the cranking speed and load. The other output starts at 30 V and is unregulated. Maximum current is 8 A. The generator uses an alternator having a samarium cobalt magnet rotor. These high-energy magnets allow the alternator to generate 200 W at a rotational speed of about 7000 rpm.

Figure 2 shows the G-76 in its present configuration together with the AN/PRC-70 radio. Interest in the device has been shown by the PM for

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[2] *Timothy F. Geiger, Performance Analysis of the R Code System for Laser-Guided Weapons (U), Harry Diamond Laboratories, draft. (CONFIDENTIAL)*

[3] *TRADOC TRMS No. 9-CEP035 TRADOC ACN 23136: Concept Evaluation of Tank Appended Crew Evaluation Device (TACED), Breadboard Model, US Army Armor and Engineer Board, Ft. Knox, KY 40121.*

Nuclear Weapons. HDL has been requested to provide 146 units for use with the M753 8-in. nuclear projectile to power PAL devices and the fuze setter. Three units have been supplied to the Marine Corps Development Evaluation Center, Quantico, VA. Four units have also been supplied to the Swedish government for their evaluation.

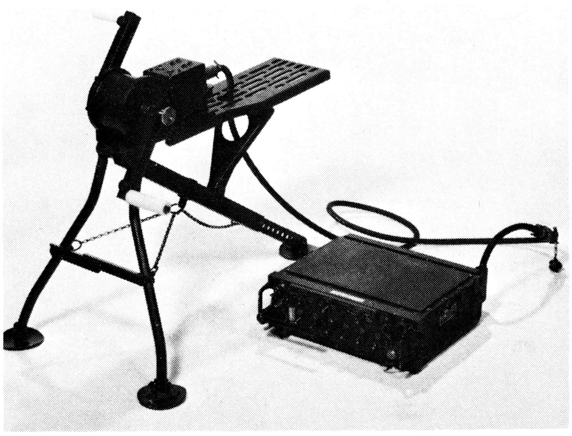

Figure 2. G-76 hand-cranked generator with AN/PRC-70 radio.

Ultrasonic Flowmeter Program. The potential environmental and safety hazards of leaks from offshore oil pipelines have resulted in the US Geological Survey (USGS) sponsoring a program at HDL to identify pipeline measurement techniques that can be applied effectively and efficiently during operations on the outer continental shelf. In particular, flowmeters were sought that could measure the flow of hydrocarbon liquids containing salt water, sand, and other sedimentary materials. After an initial survey of flowmeter technology, the ultrasonic, time-delay type of flowmeter was chosen for further evaluation. These meters also have the advantage of not intruding into the pipeline, allowing free passage of pipeline pigs without the necessity of a pig bypass around the meter.

Commercially available meters were purchased and tested at a meter-proving facility at the input of a major refinery. Measurements were made of meter linearity and repeatability over a wide range of crude oil flow rates and viscosities.

The data gathered during these tests provided a statistical basis for a computer simulation of meter performance in a leak-detection configuration. The simulation showed that, for one of the meters tested, the probability of detecting a leak greater than 0.6 percent of the total flow in 10 minutes could be greater than 99 percent. The probability of a false alarm for the same conditions is 0.1 percent. The study concluded that, for long pipelines, it may be possible to improve transient-leak-detection accuracy by making intermediate flow measurements with ultrasonic meters.

chapter 3. technical support operations

One of the most important indicators of the success of any organization is the ability of its personnel to respond effectively to the goals and missions of the organization. In an R&D environment, it is the scientists and engineers who fulfill the primary missions and usually receive the kudos; however, many of their goals cannot be met without the assistance of a competent and dedicated support organization. The Technical Support Organization at HDL is a part of the HDL team, and the success of personnel on the scientific side of the house is, in no small measure, the result of the support they receive from their administrative counterparts. This chapter of the laboratory review for FY79 is intended to illustrate how a support team, organic to the scientific organization, provides for and enhances the accomplishments of the scientific members.

Civilian Personnel Office. This Office is responsible for servicing personnel of HDL, HQ ERADCOM, and BETA. The specific programs and accomplishments for FY79 are provided.

Personnel Summary. In FY79, the number of employees at HDL subject to the personnel ceiling was 1158. Of this number, 62 were temporary or part-time employees. This compares with 1182 total for FY78 when there were 1141 permanent and 41 temporary or part-time personnel. The increase in temporary personnel reflects temporary workload increases requiring additional personnel.

Labor Relations. At the beginning of FY79, HDL was served with a Notice of Hearing from the Department of Labor. The purpose of the hearing was to determine the appropriateness of a proposed bargaining unit consisting of all nonsupervisory wage grade employees at HDL not under exclusive recognition. The unit was being sought by the American Federation of Government Employees (AFGE), which also represents two HDL bargaining units: the guards and the custodians. The position of HDL management was that an all wage grade unit was not appropriate for recognition. The employees in the unit did not share an identifiable community of interest distinct from other employees of HDL. Furthermore, HDL management maintained that the proposed unit would contribute to fragmentation and, therefore, could not reasonably be expected to promote effective dealings or efficiency of operations. AFGE withdrew the petition for the wage grade unit before the hearing. The Department of Labor informed AFGE that it could file no petition for the same unit or any subdivision for six months from the date of withdrawal.

Immediately following the withdrawal of the petition, in late October, AFGE requested HDL to enter into contract negotiations with them. Ground rules for negotiations were established in early March. An HDL Management Negotiation Team was designated by the Commander in early May and actual negotiations for a contract covering both the guard and custodial units began on 30 May

1979. The negotiations have continued throughout FY79 and will continue during FY80. As part of the contract, AFGE sought a flexitime program for its janitorial force. HDL agreed to a 120-day trial program for the janitorial force; this program is scheduled to begin in FY80.

Senior Executive Service (SES). The Senior Executive Service was created by the Civil Service Reform act of 1978 to enable the Federal Government to provide its senior civilian executives enlarged opportunities for distinctive recognition and compensation based on performance, increased career mobility, and greater development opportunities.

The SES includes managers at GS-16 through Executive Level IV or their equivalent in the Executive Branch. Early in 1979, SES positions were identified in each agency. Individuals who occupied these positions were given 90 days in which to choose either to enter the Service or to remain under the present authorities.

All eligible employees elected to enter the SES and actions were processed to document the required changes. These SES conversions were effective on 13 July 1979. Seven employees were involved: three at HQ ERADCOM, three at HDL, and one at BETA.

Grade and Pay Retention. Title VIII of the Civil Service Reform Act (CSRA) of 1978, signed into law on 13 October 1978 (Public Law 94-454), provides for grade and pay retention under certain circumstances when an employee's grade or pay would otherwise be reduced. The effective date of these provisions is the first day of the first pay period beginning on or after 11 January 1979. Title VIII also provides for retroactive entitlement to certain employees reduced in grade on or after 1 January 1977, and before the effective date of Title VIII.

All employees serviced by the HDL Civilian Personnel Office who were reduced in grade during the above period were furnished with Office of Personnel Management (OPM) Form 1367 (Claim for Retroactive Pay Entitlement Under the Civil Service Reform Act) early in June. All employees' claims were reviewed for eligibility and the necessary actions processed by the first week in September and forwarded to the Payroll Office. All eligible employees received two actions, one to document the grade restoration and the other to document grade retention.

A total of 35 employees were entitled to grade restoration and grade retention; 9 employees either retired or had been repromoted back to their higher grades, 4 employees who filed were ineligible, and 3 employees eligible chose not to file at this time.

Employees who retained their grades as a result of the CSRA were counselled and registered in the DoD Priority Placement Program (PPP) for consideration for DA vacancies in the commuting area. If employees decline valid job offers, they will no longer be able to retain their grade and pay nor be eligible for further referral through the PPP.

Recruiting Brochures. The PAO and CPO developed a recruiting brochure to assist in the recruitment of Engineers, Work Study employees, and Summer Employees. The purpose is to facilitate the recruitment of engineering and scientific personnel.

Upward Mobility Program (UMP). During FY79, a UMP participant completed the training requirements and graduated from the program. Four additional employees entered the program through competitive procedures.

Major Reorganization within HDL. On 1 July 1979, a reorganization took place within HDL when the Administrative Support Office (except for the Travel and Transportation Branch) was combined with the Technical and Visual Information Office, previously a major component of the Industrial Engineering and Technical Support Division. The new organization, called the Technical Information and Administrative Office, now reports directly to the Command Group; the Travel and Transportation Branch is now a branch of the Logistics Management Office. The reorganization was intended to consolidate logistics and administrative functions within HDL under offices that report directly to the Command Group.

Review of GS-13 Positions. In April 1979 the Commanding General of ERADCOM directed that engineering and scientific positions at GS-13 and above be thoroughly reviewed and evaluated by either the OPM Research Grade Evaluation Guide or the Experimental Development Grade Evaluation Guide. The type of review chosen was the preferred OPM/DA approach, using a joint technical expert panel and position classifier. This approach requires first that each individual's personal qualifications and contributions be reviewed by a panel of technical experts who make recommendations to the servicing position and pay management branch; second, that other appropriate factors, such as the research situation, assignment, supervision received, guidelines, and originality, be evaluated by a position classification specialist; and third, that a final evaluation by a supervisory position classification specialist be made taking into account both previously described inputs. This review affects approximately 125 HDL personnel, requiring them to develop in-depth personal qualifications briefs describing such factors for research positions as their leadership roles within their organizations; the type, quantity, and impact of their publications, inventions, designs, and so on; and the degree and type of recognition they have received from the scientific community.

Staffing.

Strength. In FY79, HDL civilian personnel strength subject to ceiling was 1158. This represents a decrease from the FY78 total of 1182. The HDL Civilian Personnel Office is also responsible for serving ERADCOM Headquarters, whose strength rose from 102 in FY78 to 166 in FY79. Thus, there was a concentration of effort to fill the Headquarters vacancies. Other groups served by the HDL CPO were not included in the calculation of personnel strength just given: 50 DARCOM Personnel Support Agency, 12 BETA, 9 US Army Communication Command, and 7 Secretary of the Army Mobility, Opportunity and Development (SAMOD) program employees. Three employees are not subject to the personnel ceiling.

Student Trainees. Fifteen undergraduates in engineering and science were hired this year and five undergraduates returned for the summer. Of the 20 student trainees working this summer, three were females and one was a member of a minority group. One student trainee is a handicapped employee.

Federal Junior Fellowship Program. Four new Junior Fellows were hired this year, bringing our total to 16. These 16 include five minority and nine female (three minority) students.

Summer Employment Program. This program provided work opportunities for 71 high school and college students, affording them gainful employment while enabling them to use their academic skills and knowledge.

Cooperative Education Program. During FY79, 15 Co-Op students (including three females) were hired from Drexel University, Virginia Polytechnic Institute, University of Maryland, George Washington University, and Howard University. Five Co-Op's, including one minority, left the program as undergraduates and seven earned their degrees but accepted positions with private industry at higher starting salaries. At the end of the fiscal year, 11 Co-Op's were on board and 11 were on leave without pay while attending school. Of the 22 current Co-Op's, three are females, one is a minority, and one is a handicapped student.

Vocational Office Training Program. Of the 16 high school seniors in the program for the 1978-1979 school year, 10 were employed at HDL upon graduation. Twenty-one students were hired from five area high schools for the 1979-1980 school year.

Average Grade Calculation. The average grade of HDL employees at the end of the last three fiscal years is shown in table 1. HDL lost 45 full-time employees during the year, but these employees represented such a span of grades that their loss did not materially affect the average grade. The slight change in average grade does not, however, necessarily reflect a stabilized situation in FY79. Because of quota limitations on high grade positions (GS-13 through GS-15), very few promotions were made to those grades compared with potential requirements

and past practice. These figures are also misleading because of the continuing high number of professional scientific and engineering positions, GS-9 through 11, remaining unfillable. Average grade control will be appropriately managed by the Commander and Technical Director and their staff to assure that the assigned average grade for HDL is not exceeded in FY80.

Table 1. Average Grade on 30 September

Category	FY77	FY78	FY79
Full-time permanent	10.1802	10.1363	10.1411
Full-time permanent and temporary	10.0685	10.0354	9.9704

Training. During the past year a high level of training activities was provided through a variety of local DoD, interagency, and nongovernment training. A greater number of people attended training courses during FY79 than during FY78 (918 versus 735). There were significant increases in self-development efforts by HDL/ERADCOM employees. These efforts are reflected in the number of employees who now use correspondence courses as well as college level courses to attain needed skills during personal time.

Most HDL/ERADCOM training needs are being accomplished satisfactorily. Employees are taking advantage of the DoD school allocations, especially since the "face-the-space" program began. (In this program, slots for training must be requested for particular people.)

Special focus was given to the interns, both SAMOD and DARCOM. Formal training and on-the-job assignments were provided as required by the individual programs of instruction.

Training plans have been established for the four new upward mobility participants selected during FY79. It is still too early for much of the planned training to have taken place. Both employees and supervisors are expected to be involved to assure that training coincides with the proper use of the employees' skills and job responsibilities.

The in-house courses provided for HDL and ERADCOM Headquarters personnel are mainly technical (data processing); however, in addition to these, employees were able to attend on-site seminars and various workshops, including two on secretarial skills and others on Conference Leadership, Effective Briefing, Installation Equipment, and Leadership and Management Development.

The overall training effort consists of many interrelated activities that build upon one another to form a plan that becomes the basis for effectively managing human resources. The FY79 training activities are shown in table 2.

The summer employment program offered career opportunities to particularly able high school and college students (107) in professional, administrative, and technical positions. The overall program includes the following categories of employment.

- The Student Trainee Program offered summer employment to 20 high-caliber undergraduates; HDL hopes to hire these students for permanent science and engineering positions on graduation.
- The Federal Junior Fellowship Program, initially offered to high school students graduating in the upper 10 percent of their classes and accepted by accredited colleges, provided 12 returnees and four new hires.
- The other category of summer employment, "Summer Hires and Summer Aides from the Employment Examination," provided other technical and nontechnical opportunities to 71 high school and college students.

The new employees attended an orientation which included a tour of the laboratories and offices. Science and engineering students participated

Table 2. Training Activities

Type of training	Participants No.	Participants %[a]	Training facility[b]
Executive/	29	2	DoD
Managerial	14	1	Interagency
	8	—	Nongovernment
Supervisory	11	—	DoD
	5	—	Interagency
Technical	283	23	DoD
	74	6	Nongovernment
	20	1.5	Interagency
S/E and legal	26	2	DoD
	183	15	Nongovernment[c]
Administrative	114	9	DoD
	77	6	Nongovernment
	74	6	Interagency
Total	918		

[a]*Percentage of total workforce*
[b]*Total DoD—39%*
Total interagency—9%
Total nongovernment—29%
[c]*Nongovernment includes all college and university training.*

in the annual symposium. At the end of the summer, the students attended a picnic where information was given them on career opportunities with the federal government.

Management Information Systems Office. The Management Information Systems (MIS) Office provides complete automatic data processing (ADP) services to HDL and tenant activities involving both scientific and business computing functions. Data processing supporting all administrative areas is centralized in the MIS Office, while scientific computing support varies from user training and assistance to complete application development. The IBM 370/168 computer is operated in support of both scientific and business requirements.

The MIS Office improved its support of ADP requirements to HDL, HQ ERADCOM, and other tenant or contract activities by the addition of both hardware and software. Because of the number of changes in MIS support, a new computer User's Guide was developed and will be issued in the fall of 1979. The IBM 370/168 computer workload has grown to the point where rates will be reduced for operation in FY80.

Development efforts for administrative systems during FY79 were aimed at providing interactive data base systems for new users, proceeding with the plan to integrate and improve the systems previously implemented, and responding to ERADCOM requests.

Software Branch. New data bases include the following:

- Storeroom supply—for storeroom supplies and loading dock receipts,
- SPO—procurement data base for small purchases, and
- PROMANDIS—a Programs and Plans top management level data base for tracking summary cost/performance data and projecting planning information.

A major integration study was performed in the Comptroller area to guide the effort to provide expanded ADP service. This study resulted in modified data base structures for the Cost Accounting and Funding data bases. Along with analysis and design efforts for the other data bases, the results of the study have facilitated the design of integration links among Cost Accounting, Funding, Contracts, Small Purchases, PROMANDIS, and Storeroom Supply data bases. Some of these augmentations and revisions have been implemented. Others are in the latter stages of design and testing and will be implemented early in FY80.

Much progress was made in data-entry front-ends. The full-screen processing facility, developed at HDL for use with IBM 3279 CRT terminals, is being used to great advantage in implementing data edit/input programs that make on-line data entry

convenient and easy to use for functional personnel. Full-screen front-ends have been developed for the Funding, PROMANDIS, Small Purchases, Contracts, and Storeroom Supply data bases and for the MARDIS system; others are under development for the Cost Accounting, Employee/Labor, and Motor Pool systems.

A study of the requirements to support Finance and Accounting activities for SWL has resulted in a planned implementation date of 1 October 1980.

A number of enhancements to the computer operating system were installed, including several selectable units distributed by IBM. Operating system maintenance was kept up to date, as was maintenance of all compilers and general-purpose application programming packages. The procurement of a data security package (ACF2) was initiated but not completed. Software was developed locally to provide full-screen support to application programmers in higher level languages, and several other software packages were developed to improve system response and performance.

There were many additions to the software features available for the IBM 370/168 users. More than 30 user-oriented TSO commands and CLIST's were written. The ACSL (Advanced Continuous Simulation Language) product was installed and tested. Interface software between PR1ME and IBM was written, enabling better communication between the two computer systems. Various subroutines were written to make it easier to write programs using the full-screen input possible with the IBM 3270 terminals distributed throughout the laboratories. This new capability has been applied to a motor pool application and to RECALL, HDL's inhouse data base system. RECALL has also been augmented with more plot and other commands.

The Programming Assistance Group (PAG) continues to provide analysis and programming support to the S&E areas as well as to the general user as needed. Some specific examples follow.

- a general message system (devised for ERADCOM, but adaptable for all user groups)
- an interactive software system for the HP1000 minicomputer, to aid engineers in designing electronic circuits
- statistical analyses of fuze data
- ERADCOM message log system and manuscript review form
- documentation and maintenance of the TD/CMS (technical data package for HDL Laboratory 47100)
- conversion of the FLUID program that processes test results for fluidic logic units to the 370/168, for Laboratory 13000
- statistical analysis of acceptance test data for the M728 battery

PAG also teaches computer-related courses throughout the year, and contributes articles to the User's Guide and monthly newsletter.

SPEAR. The SPEAR network is a distributed intelligence computing network based on a hierarchical structure, with the IBM 370/168 as the main computational processor. Three PR1ME 400 computer systems provide interactive support for the laboratories in the areas of program preparation, communications, graphics, data entry, and data acquisition. Direct connection between the laboratories and SPEAR allows high-speed terminal communications (up to 9600 baud) without the need for modems.

Command-level programs have been written for compilation and execution of FORTRAN programs, and for providing help to users on the network. Two methods of access to the 370/168 are planned: batch, through the HASP protocol (which is currently running), and interactive, through the 370/168's time sharing option (TSO). Provision has been made to store and fetch programs and data from the 370/168 as quickly as possible, with minimum effort by the user. A general-purpose data-plotting command and subroutine package is being written to provide easy and consistent graphics display for computer-generated or -reduced data.

The front-end equipment, delivered by PR1ME Computer, Inc., is connected via a fiber-

optic digital-communications network throughout HDL's main laboratory complex and AURORA; 240 communications channels will be provided, with 128 going to SPEAR. Each fiber-optic pair will carry up to 16 full-duplex terminal communications at asychronous rates up to 9600 baud and at synchronous rates up to 150 kbaud.

Operations Branch. The Operations Branch has undergone many significant changes which have enhanced the overall support for HDL and tenant activities. A Maintenance Activity data base has been established. It provides details on effective production time; scheduled, unscheduled, and remedial maintenance downtime; idle time; residual time; and setup time. Information in this data base provides management with indicators of computer performance.

With the increased computer workload at HDL, advanced job scheduling has become important. To aid in this area, the Operations Branch has implemented an Automated Scheduling data base system. Users requiring special job handling are notifying the ADP scheduler in advance. This information is fed into a data base and daily utilization reports are generated to provide operations with overall workload requirements. Benefits from this system are (1) timely production schedules and (2) controls needed to maintain high levels of performance.

A Tape Library Maintenance system is currently being designed which will update the current tape system and provide accurate tape references and automatic tape releases after a designated time period.

The increased processing workload has affected the MIS Office's printed output volume. To handle this area, the Operations Branch has a Paper Inventory Supply system which accurately identifies types of paper and storage locations. This system aids the operations staff in maintaining adequate paper supply levels for in-house printers. Additionally, it provides on-order information and expected arrival dates.

Several Army standard systems are being run by the Operations Branch. These systems were implemented, tested, and documented for production running. The systems include TRACE (Total Risk Assessing Cost Estimate), AUDIT (Army Uniform Data Inquiry Technique), and ITAADS (Installation Army Authorization Documents System). Currently, the Operations staff is working with the Software Branch on two additional standard systems: STARCIPS (Standard Army Civilian Payroll System) and MARDIS (Modernized Army Research and Development Information System). Once procedures are developed, these systems will be handled by the operations staff.

The computer accounting system has been changed to include weekly reporting. This allows computer costs to be distributed to user projects more quickly. In addition, the responsibility for running detailed reports for computer account status has been transferred to the users through an on-line interactive access method which provides current account information. This has resulted in significant savings both in paper output and in man hours spent distributing reports that many users never read.

A program has been written using FY79 statistics to measure the impact of various rate changes on the revenue from users.

During the year, renewals of hardware and software contracts were centralized within the Operations Branch. New procurement during this year has included an expanded terminal system for administrative applications, a block multiplexer to replace the selector channel, additional disc storage, and a new high-speed print train.

The Reports Control function has been implemented into an on-line data base that expedites report generation and provides up-to-date information for RCS and PCN registers.

Statistics on workload on the IBM 370/168 are collected. Graphs are produced comparing workload each fiscal year and comparing various

classes of users (for example, business users as opposed to S&E users).

Technical Information and Administrative Office. One of the most important functions of HDL is the effective dissemination of R&D information—whether through formal reports, oral presentations, scientific journals, or trade publications. HDL scientists require prompt technical information support and technical report services for the efficient exchange of information between HDL and the "outside world." To insure that these important functions could be scheduled and performed in the most efficient and cost-effective manner, the Administrative Services Office and Printing and Reproduction Branch were placed organizationally under a new office as designated above. The specific accomplishments of these organizations are enumerated.

Technical Library. During FY79, the Library circulated 14,784 books/reports and provided 32,959 reference items. Aside from the established liaison with other reference libraries, such as the National Bureau of Standards and the Library of Congress, the HDL Library has available a number of systems for computerized information searching. The many systems that are available provide access to hundreds of data bases. For example, one system (Lockheed) can access more than 100 data bases; among them are the National Technical Information Services (NTIS), Chem Abstracts, Scisearch (Citation Index), and Conference Papers. Two other systems in use are SDC (Systems Development Corporation) and LibCon (Library of Congress). The number of data bases available for computerized information searching is continually increasing.

Bibliographic information is available immediately through computer terminals in the HDL Library. Requests for hard copy can be filled in a matter of days or weeks—the usual turnaround time is two days.

Technical Reports. The Technical Reports Branch processes several different types of manuscripts. Highly specialized editorial teams see a formal HDL report through all stages of its preparation—from editing to composition to layout (camera-ready copy for the printer). Manuscripts that are editorially reviewed include proceedings papers, oral presentations, contractor reports, and the annual posture report. In FY79, 346 manuscripts were processed, for a total of 15,277 manuscript pages.

Both editors and production personnel are available to those in need of their particular expertise. Editors can help authors in the planning, organization, and writing of reports. Production personnel can aid those learning to use new word-processing and photocomposition equipment.

Visual Information. The Visual Information Branch coordinates or produces all visual material used or published by HDL—displays, exhibits, and illustrations for internal and external reports. The audiovisual projection equipment associated with the HDL auditorium is operated and maintained by this office.

Table 3 shows the number of work orders for the Graphics and Photography Sections for FY79.

Table 3. Work Orders for Graphics and Photography Sections

Work orders	Graphics Section	Change (%) from FY78	Photography Section	Change (%) from FY78
Received	1115	+3	1859	−7
Completed	1091	+7	1872	−6
In house	570	+5	1594	−17
Contracted	521	+9	278	+187

Administrative Services. The functions of this branch include all mailroom services, records management, and approval for word-processing equipment. Continued manpower shortages have slowed the implementation of operating procedures to improve the organization and production flow. These new procedures will be implemented during FY80. In-house mail pickup and delivery was partially reestablished late in the fiscal year.

Printing and Reproduction. This branch is responsible for providing printing, duplicating, and binding

services to HDL and tenant activities. The number of items (bound volumes, technical reports, manuals) printed in-house and on contract for the last four years is shown in table 4.

Table 4. Printing Activity

Fiscal year	In-house impressions	Contracted Items	Contracted Impressions
1976	4,163,364	21,126	1,548,637
1977	4,164,800	17,141	2,380,401
1978	5,409,891	21,667	2,457,600
1979	4,992,422	25,586	2,575,762

The branch was instrumental in securing authorization for ERADCOM to print by contract the ERADCOM newspaper, with a three-day delivery commitment. The paper has a monthly volume of 5000 copies.

Another significant achievement was the conversion from lease to purchase of one automated duplicating system (Xerox 9200) at a cost of $57,000 through the Quick Return Investment Program. The cost of the equipment will be completely amortized in 24 months; consequently, the government will save more than $100,000 over a period of 5 years.

Procurement. The HDL and Vint Hill Farms Contracting Offices have, as their direct mission, the support of HDL and SWL, respectively. Additionally, the Procurement Office has been tasked, either through Intraservice Support Agreements or at the request of HQ ERADCOM, to provide "extramission" support to various other agencies. Table 5 shows the total contracts awarded in FY79. Table 6 shows the number of contracts let by the office both as part of the direct mission and as extramission support. (Also see fig. 1.)

The significant accomplishments of the Procurement Office for FY79 include the awarding of several M587/724 fuze system contracts. These awards were for the Initial Production Facilities for the electronic head and the PS127 power supplies,

Table 5. Contracts Awarded in FY79

Types of contracts	Quantity	Dollars (millions)
Actions over $10K	437	210.9
Actions under $10K	11,510	5.3
Sole source		
Over $10K	344	121.5
Under $10K	10,940	4.1
Competitive		
Over $10K	93	89.4
Under $10K	570	1.2
Nonprofit or other		
Over $10K	22	1.7
Under $10K	1,381	1.7
Large business		
Over $10K	288	195.6
Under $10K	2,003	1.5
Small business		
Over $10K	127	13.6
Under $10K	8,126	2.1
Small business program goal	NA	9
Small business program performance	NA	15.4
8(a) program assigned goal	NA	0.5
8(a) program performance	NA	0.11

and three-year, multi-year production contracts for the electronic head, the PS127, and M36 fuze setters. The awards, all placed on a firm fixed-price competitive basis, were at a total dollar value many millions of dollars below the government's original estimates. Also of note were the multimillion dollar contracts awarded for the AN/MLQ-33 countermeasures system, the AN/MSQ-103 (TEAMPAC) receiving set, the AN/MLQ-34 (TACJAM) countermeasures system, and the AN/TSQ-114 (Trailblazer) detection system. The AN/MLQ-33 and the AN/MSQ-103 were placed competitively.

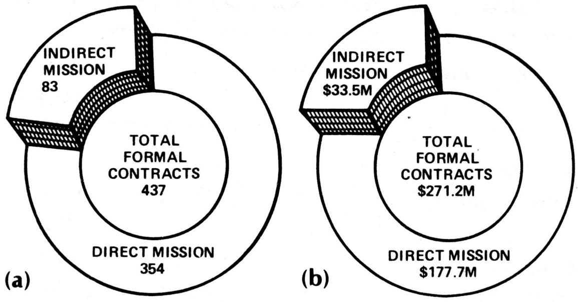

Figure 1. Direct and indirect mission support: (a) actions and (b) dollars.

Table 6. Direct- and Extra-Mission Support: Contracts, FY79

Type of support	Agency[a]	Number	Dollars (millions)
Direct	HDL	234	68.2
	SWL	120	109.5
Total direct mission		**354**	**177.7**
Extra	BETA	6	13.9
	CAS	12	1.7
	DARCOM	12	1.5
	DSMC	2	0.7
	ERADCOM	11	0.3
	EWL	2	0.3
	FSTC	16	1.2
	IMDSO	2	1.2
	PMCAC	2	10.3
	TRADOC	17	2.3
	USAISD	1	0.1
Total extra mission		**83**	**33.5**

[a]*See Acronyms and Abbreviations for Agency names.*

BETA (Battlefield Exploitation and Target Acquisition) has been a joint service development effort with a four-set procurement process. The Letter Contract was made definite on 28 August 1978 for $4.5M. Since that time, 16 modifications have been issued, resulting in an overall estimated cost plus maximum fee of $29M. BETA will be demonstrated in CONUS and Europe during 1980 and 1981.

The marked increase in actions for FY79 over previous years is due primarily to the addition of the Vint Hill Farms Contracts Branch and the related SWL procurement mission. The office (Vint Hill and Adelphi) has an authorized staff of 64, but has functioned for the last year at approximately 85 percent of strength (with most of the vacancies in the high grades) and an attrition rate of 20 percent a year. Since contract specialists are in high demand in the Washington area, it is difficult to retain key personnel.

During FY79, the contracting office had full use of its formal Contracts Data Base Management Information System. The Small Purchase Data Base Management Information System was brought on line in late September. The automation of procurement data proved to be an invaluable managerial tool throughout the year. The system provided information in response to both internal and external queries, thereby freeing contracting personnel to perform contract-related functions; this system therefore helped make possible the high productivity achieved despite the office operating at only 85-percent strength. The system enabled managers to analyze performance, control contract action flow through the procurement procedures, and anticipate problem areas and bottlenecks.

It is expected that the Small Purchase Data Base Management Information System will have an even greater impact on lessening the administrative workload, especially statistical reporting, follow-up, and timely payments of invoices.

In addition to the Data Base Management Information System, the Office recently acquired a Wang word-processing system. The system has demonstrated its value in the contracting area by enabling operators to select specific contract clauses applicable to a particular type of contract and have them reproduced in any combination necessary, as frequently as desired, and with perfect accuracy. Many other applications of the sys-

tem are being explored and implemented as system software is developed and documented.

Office of Legal Counsel. The Office of Legal Counsel provides legal advice and services to the Commander and his staff in the fields of acquisition, intellectual property, and all other business and commercial law matters arising in the administration of HDL. Legal support of all aspects of appropriated fund acquisitions is provided from inception of requirements through the solicitation, award, administration, and close-out of contracts. The office coordinates protests against awards filed with the General Accounting Office, higher commands, and the contracting officer, and processes appeals by contractors to the Armed Services Board of Contract Appeals against final determinations of contracting officers.

Legal Counsel and services provided in non-acquisition-related matters include areas such as civilian personnel actions, labor relations, employee standards of conduct, security requirements, release of information, claims by and against the United States, congressional inquiries, real and personal property actions, external audits, environmental law, intra- and inter-service support, nonappropriated fund activities, and litigation, hearings, or investigations involving matters arising in the administration of HDL. In matters involving intellectual property, the office evaluates, reviews, and screens potential contractor inventions; maintains contract follow-up on patent provisions; investigates patent infringement claims; counsels operating personnel on patent rights, technical data, copyrights, and other proprietary rights; evaluates employee invention disclosures; and prepares and prosecutes applications for patents in conformity with US Trademark and Patents Office policy.

In FY79 legal services were provided for HDL and organizations supported by HDL, including Headquarters DARCOM, Headquarters ERADCOM, TRADOC, FSTC, the BETA Project Office, SWL, TECOM, and the Study Management Office, ASA. One attorney was assigned full time to provide on-site full-time legal support to SWL at Vint Hill Farms Station (VHFS).

During the year, the office completed approximately 675 formal reviews of acquisition actions, coordinated six protests, and handled approximately 200 formal general or administrative law problems. In addition, a significant amount of professional time was spent in board actions and meetings, and in providing legal counsel and services in response to informal requests for assistance. Patent counsel received 44 employee invention disclosures and prepared and filed 33 applications with the Patent Office. During FY79, 35 patents were issued to HDL inventors, the applications for some of which were filed in previous fiscal years.

Logistics Management Office. The establishment of the Logistics Management Office during FY79 has provided a common management point for the Supply Management, Transportation Management, Maintenance Management, and Equipment Management Branches. This reorganization allows problems in these activities to be resolved through a single organization, the Logistics Management Office. Specific milestone accomplishments follow.

- The existing TMDE (test measurement and diagnostic equipment) calibration recall and scheduling data base (System 2000) was expanded to include expendable property. The expanded system provided terminal-accessed visibility of all installation equipment shown on the property book records and will serve as a tool to enable hand-receipt holders (who have supervisory or direct responsibility for government property) to trace the current (or last recorded) location of any item in their property book accounts.

- The automated data base system for supply management was completed and implemented. This system is the long-awaited replacement for the ADP Supply Management capability that was lost in 1975 when HDL records were converted from the IBM 7094 to the new IBM 370/168. The system includes provisions for computing or generating requisition objectives, reorder points, suggested order quantities, inventory schedule, and the numerous recurring supply management reports required to be submitted to higher headquarters.

• Also completed was the preliminary phase required before implementation of the Installation Equipment Management System (IEMS). The steps involved included (a) placement of a contract for file development assistance through the Small Business Administration, (b) training of all functional personnel who are involved in IEMS implementation and operation, and (c) selection of two accounts as prototypes for development of the catalog file. The completion of the preliminary phase will facilitate the timely and orderly implementation of IEMS as directed by DARCOM.

Facilities Engineering Office. The Facilities Engineering Office is responsible for real property Maintenance and Repair (MR), buildings and grounds, (including building and underground utility systems), custodial services, entomological services, fire prevention, intrusion-detection systems, Military Construction Army (MCA), master planning, engineering support services, environmental impact assessments (EIA's), energy control, the space utilization program, and real property inventory. These services are provided by 121 employees at four installations: Adelphi, Blossom Point Field Test Site, Gaithersburg Research Facility, and Woodbridge Research Facility. Various MR and engineering services are contract supported as the need arises. These services are also provided for HQ ERADCOM and BETA.

Maintenance and Repair. The HDL Facilities Engineering Office's principal activity and expenditure of resources is in the performance of Individual Job Orders (IJO's), Standard Operating Orders (SOO's), and Maintenance Service Orders (MSO's). (These activities are reflected by quarter in table 7.) The IJO's and MSO's are generally in direct support of the technical programs of the laboratory, whereas routine preventative maintenance and repair is performed through the SOO's.

MCA Program. An MCA Project Summary for FY80 through FY85 was completed and submitted. This summary includes current approved projects as well as short-, intermediate-, and long-range projects. Examples of current projects are the construction of a new Microelectronics Facility and the installation of an energy control and monitoring system, both at Adelphi. Short-range projects (before FY84) include the addition of solar screens and storm windows at Adelphi and the acquisition of land at Blossom Point. An intermediate-range (FY84) project is the addition of a sixth floor to the administration building at Adelphi. Long-range projects include the construction of such facilities as a Research and Engineering Support Annex, a Fuze Environmental Simulation Facility, and a Microwave Antenna Range.

Master Planning. A schedule for the update of the Master Plan has been completed. This Master Plan concerns all four sites: Adelphi, Blossom Point, Gaithersburg, and Woodbridge.

Environmental and Energy Management. The Environmental and Energy Management Program is

Table 7. FY79 Work Orders Completed[a]

Work orders	First quarter		Second quarter		Third quarter		Fourth quarter		Total FY79	
	No.	MH	No.	MH	No.	MH	No.	MH	No.	MH
IJO's	66	8,211	77	6,996	78	9,305	86	11,072	307	35,584
SOO's	60	24,824	62	26,550	60	26,198	60	26,015	242	103,587
MSO's	1,048	4,443	1,044	3,378	907	3,568	999	3,796	3,998	15,185
Total	1,174	37,478	1,183	36,924	1,045	39,071	1,145	40,883	4,547	154,356

[a]*IJO = Individual Job Order* *MSO = Maintenance Service Order*
SOO = Standard Operating Order *MH = Man hours*

accomplished by the HDL Energy/Environmental Coordinator, a member of the Facilities Engineering staff. The Energy Environmental Coordinator is assisted in his work by a support services contract, which provides professional staff as required in managing this program.

Environmental Impact Assessment. The Energy/Environmental Coordinator prepared an annual Installation Environmental Impact Assessment (IEIA) and eight EIA's in support of the MCA program during this fiscal year. The office provided guidance to various HDL staff for the preparation of 10 mission and mission-support EIA's, and provided staffing for HDL EIA's for final approval by the HDL Commander.

Environmental Pollution Control. The Environmental Coordinator's office is responsible for monitoring and reporting air, water, and noise pollution control techniques and violations. HDL is considered to be a minor air-pollution source by EPA criteria, and is in compliance with all air-quality regulations. HDL is also in accordance with current water-pollution control regulations. HDL has no major continuous noise sources, and therefore is in compliance with noise-pollution regulations. During 1979, several new water-pollution control projects for increased environmental protection were proposed and are awaiting approval from higher commands.

Radiation Pollution Control. All electronic sources of ionizing radiation at HDL are in compliance with the protective measures specified by OSHA and current US Army regulations. All radioactive materials possessed by HDL are used in accordance with the protective measures specified in the US Nuclear Regulatory Commission licenses which apply to them. No actions were taken in this area during 1979.

Solid Waste Management. A comprehensive waste paper recycling program for Adelphi and Woodbridge was implemented during 1979. The program is expected to generate approximately $5000 a year in revenue sales for HDL.

Toxic and Hazardous Materials Management. HDL does not handle significant quantities of toxic materials except for pesticides for its insect/pest-management program, and petroleum fuels for general heating operations; these substances are used in accordance with federal and Army regulations. A Hazardous Substance Spill Control and Contingency Plan and an Installation Spill Contingency Plan have been prepared for all HDL sites. These plans provide procedures and programs for the management of hazardous materials and controls for potential spill incidents.

Land Management and Conservation. The various flora and fauna on HDL sites are maintained and protected through several active conservation programs developed by the Environmental Coordinator's office.

A Natural Resources Fish and Wildlife Management Program has been initiated in conjunction with resource conservation activities at HDL. Fish, waterfowl, deer, and small mammals found in the woodland areas on the Woodbridge and Blossom Point sites are provided with appropriate food and shelter through this program.

The Blossom Point site contains a brick structure which has been determined eligible for the National Register of Historic Places. This historically significant structure, known as the Ballast House, was constructed between 1790 and 1815. HDL is in the process of saving the Ballast House from wind and tidal erosion, and plans to relocate the structure to preserve its integrity.

Energy Conservation. HDL has achieved many of its energy conservation goals during this period and has established several programs to surpass this achievement. An Energy Conservation Investment Project was developed during 1978 for modification to the Adelphi Boiler Plant. An Energy Advisory Group has been established to guide and implement the energy conservation programs. In addition, an Energy Conservation Incentive Awards Program was established to foster conservation awareness within HDL.

Energy and Environmental Training. The Environmental Coordinator and appropriate Facilities Engineering staff have attended the several federal, Army, and DARCOM conferences and workshops for Environmental Management and Energy Conservation in an effort to continue expanding personnel knowledge and capabilities.

Security Office. The Security Office is responsible for maintaining the overall security of HDL. Security Office functions include providing physical security support for HDL and its tenant activities at the Adelphi site, Woodbridge Research Facility, Gaithersburg Research Facility, and Blossom Point Test Facility. Other functions include maintenance of the personnel security program and information security program, as well as acting as a liaison with other security and intelligence related agencies. The Security Office is also responsible for implementing the Army's Operations Security (OPSEC) program.

In fulfillment of its missions and functions, the Security Office emphasized upgrading the HDL OPSEC Program. The DARCOM "Trojan Horse" briefing was presented to all personnel to increase overall OPSEC awareness. The Pentagon Counterintelligence Force (PCF), 902nd MI Group, performed an Operations Security Evaluation (OSE) for the Adelphi facility. The evaluation included a review of the current threat information and recommendations of "Quick-Fix" measures which could be used to eliminate possible OPSEC vulnerabilities. The PCF also provided a SAEDA (Subversion and Espionage Directed against the Army) briefing to all personnel.

In an effort to upgrade the Controlled Accountable Document Inventory System (CADIS), a physical inventory of all accountable documents was conducted and reconciled. As a result of the inventory reconciliation, CADIS was modified to include the appointment of administrative custodians for all organizations that maintain accountable documents. This modification provides a tighter control for accountable documents within each organization. The practice of mailing CADIS receipts to and from the Document Control Center (DCC) was discontinued; custodians are now required to hand-carry CADIS receipts to and from DCC. This policy avoids the possibility of CADIS receipts being lost in the mail and ensures a one-to-one exchange of CADIS receipts between DCC and the document holders.

Safety Office. During the year, the Safety Office conducted 158 surveys of HDL facilities and operations, leading to identification of 205 conditions in violation of safety and health standards. To date, 191 of the conditions have been corrected, with action pending to correct the remainder. Nine accidents resulting in disabling injury to civilian employees and three Army motor vehicle accidents were reported to higher headquarters.

Equal Employment Opportunity (EEO). FY79 was HDL's first full year of operation under ERADCOM and within the new HDL organizational structure (as of July 1978). Superimposed on the usual difficulties of any reorganization has been the Federal policy of reductions in overall personnel strength, average grade, and numbers of high-grade personnel; also, serious consideration has been given to the policy of contracting for services performed by certain segments of the workforce. All these factors combined to produce an EEO outlook for the year that was less than optimistic. The total HDL workforce for 1978 was 1182 (22.2-percent minorities and 21.5-percent women). In FY79, workforce strength decreased slightly (0.8 percent), to 1172. The total number of women decreased to 20.4 percent, and minority employees in the workforce decreased to 20.9 percent. Table 8, showing the distribution in the GS grade structure, reveals losses for minorities and women in all grades, except for women in the GS 10 to 12 group. In the wage grade system (see table 9), the minority posture improved somewhat in wage grades 6 through 10, and one additional woman was placed in that same grade group.

On the positive side, a number of career field positions in the office of management review and analysis and in the contracting and comptroller's offices have been filled by minorities and women. Work assignments have been developed to maximize the opportunity for these people to progress to journeyman levels within their organizations.

Table 8. Grade Distribution—General Schedule Employees

(As of 30 June FY79)

Category		FY	GS 1 to 5		GS 6 to 9		GS 10 to 12		GS 13 to 16	
No.	%		No.	%	No.	%	No.	%	No.	%
All employees[a]										
1025	100	78	160	15.6	204	19.9	416	40.6	245	23.9
1005	100	79	162	16.1	188	18.7	410	40.8	245	24.4
Minorities										
187	18.2	78	49	26.2	58	31.0	61	32.6	19	10.2
170	16.9	79	41	24.1	54	31.8	58	34.1	17	10.0
Women										
236	23.0	78	101	42.8	102	43.2	31	13.1	2	0.8
221	22.0	79	95	43.0	89	40.3	35	15.8	2	0.9

[a]*Full-time permanent employees.*

Table 9. Grade Distribution—Wage Board Employees

(As of 30 June FY79)

Category		FY	WG 1 to 5		WG 6 to 10		WG 11 to 15		Other nonsupv		All WS[a]	
No.	%		No.	%	No.	%	No.	%	No.	%	No.	%
All employees[b]												
157	100	78	46	29.3	38	24.2	48	30.6	14	8.9	11	7.0
167	100	79	46	27.5	47	28.1	47	28.1	14	8.4	13	7.8
Minorities												
75	47.8	78	32	42.7	22	29.3	12	16.0	3	4.0	6	8.0
75	44.9	79	29	38.7	26	34.7	11	14.7	3	4.0	6	8.0
Women												
18	11.5	78	17	94.4	1	5.6	0	—	0	—	0	—
18	10.8	79	16	88.9	2	11.1	0	—	0	—	0	—

[a]*Wage supervisors.*
[b]*Full-time permanent employees.*

Since the transfer of the HDL EEO functions to ERADCOM Headquarters (May 1978), two full-time permanent positions have been authorized in addition to that of EEO Officer (which transferred with the function); these are an EEO Specialist (Assistant EEO Officer for Adelphi) and an Upward Mobility EEO administrative position. These additional positions are expected to be filled by the end of 1979.

In August 1979, the Command EEO Officer (EEOO) left to attend the Industrial College of the Armed Forces (ICAF) at Ft. McNair, in Washington, DC. The on-board EEO Specialist, who acts as Assistant EEO Officer at the ERADCOM Field Office in Ft. Monmouth, NJ, is currently acting as Command EEO Officer at Adelphi.

The positions of HDL Hispanic Employment Program Manager (HEPM) and the Federal Women's Program Manager (FWPM) were both vacated during June 1979. Felipa Coleman, former HEPM, became the Chief of the Administration and Management Division of the Directorate of Personnel and Community Services in Ft. Meade, MD; Joyce Williams, former FWPM, became an intern in the Secretary of the Army's Mobility, Opportunity and Development (SAMOD) Program, and is currently interning in the EEO Office at DARCOM Headquarters. Before their reassignments, both special-emphasis program managers and the EEOO attended the DARCOM EEO/CPO Training Conference in El Paso, TX, during the first quarter of FY79.

Also during the first quarter of FY79, the existing FWP council, with new members added, was reestablished. One of its first projects was the initiation of a newsletter, entitled "Working Woman," first published in January 1979. The newsletter, which deals with issues for and about women, is published every two months. Inputs for the newsletter are encouraged from the workforce at large as well as from members of the council.

During FY79, HDL managers and supervisors demonstrated their support of the EEO program by encouraging HDL personnel to attend the cultural awareness activities held during Federal Women's Month and Black History, Hispanic, and Asian/Pacific Weeks. These activities included guest speakers, workshops, films, cultural artistic performances, and exhibits.

Activity in the Upward Mobility Program (UMP) during FY79 was encouraging with the identification of five UMP positions: an administrative assistant, an equipment specialist, two engineering technicians, and an EEO assistant.

Additionally, several employees were selected for positions which provided informal upward mobility opportunities in the procurement and comptroller career fields. Efforts are under way to stimulate greater managerial support and participation.

During FY79 a survey of skills and training of the ERADCOM/Adelphi workforce (especially at grades GS-9 and below) was considered, as a means of assisting employees to realize their full potential in the workforce. We hope that this survey will materialize during FY80.

Concerted efforts were continued, as in previous years, to eliminate and/or reduce the number of formal discrimination complaints by resolving issues informally at the lowest possible organizational level.

As in FY78, HDL again served as a field trip site for students participating in the Armed Forces Orientation to Engineering Careers (AFOTEC) and the Pre-Freshman and Cooperative Education (PREFACE) Programs. These are programs designed to attract greater numbers of minority and female high school students to federal careers in engineering and science.

Alcohol and Drug Abuse Office. The HQ ERADCOM Alcohol and Drug Abuse Prevention and Control Program (ADAPCP) underwent changes in 1979, resulting in a variety of program innovations designed to improve and strengthen the prevention and treatment services available to the workforce. The program has developed a stronger identity with the community, where more resources are available under the direction of professional medical personnel. This accounts for a high recovery rate among our personnel referred for treatment.

A workshop for supervisors and managers on recovery from alcoholism was provided by an expert in alcoholism prevention; another topic covered in this workshop was "burn-out" and how to manage it. The workshop was rated as excellent by 96 percent of those participating. Videotapes were made for greater distribution of the information throughout the Command. A general workforce awareness seminar was provided with 350 employees in attendance, featuring the Hon. Wilbur D. Mills as guest speaker.

A point of contact was named in each laboratory to interface between the host ADAPCP providing rehabilitative services and ERADCOM employees. Critical to our success in the field is the work of these volunteers to provide feedback to HQ on the services received and the quality of preventive education they are provided.

As a more neutral environment is created for the programs in the Command, stigma will be reduced, employees will be encouraged to volunteer for help, and supervisors will be assisted to make referrals through earlier identification of problems.

chapter 4. contribution/coordination

technology base

Technology base programs include those in the research (6.1), exploratory development (6.2), and non-systems advanced development (6.3a) categories. It is from the work done in these areas that fielded systems eventually arise. Thus, a strong, productive, and relevant technology base program is essential for the Army. At HDL the technology base program consists of several projects. These include the In-House Laboratory Independent Research (ILIR) program; the 6.1 program on Fluidics, Nuclear Effects, and Ordnance Electronics (AH44); the 6.2 program on Nuclear Effects, Near Millimeter Wave Technology, and Fluidics (AH25); and the fuzing portion of the ARRADCOM 6.2 program on Large-Caliber and Nuclear Technology (AH18).

ILIR. The ILIR program is unique among R&D programs because the funding allocation and technical content is at the discretion of HDL's Technical Director. He reports on progress and accomplishments directly to the Assistant Secretary of the Army for Research, Development, and Acquisition—ASA(RDA). The program is then reviewed by the Army Science Board after the fact, and subsequent support depends on how successful the program was in the previous year. This arrangement promotes innovative, high-risk, high-payoff efforts.

FY79 was an excellent year for HDL's ILIR program, which received an Army Science Board rating near the top among the 39 laboratories reviewed by the Board.

Significant results were obtained in the following programs.

- The Army urgently needs a simple, reliable test for the radiation hardness of metal-oxide-semiconductor (MOS) devices that does not require direct radiation exposure. A high-field electron injection and impact ionization test was conceived and evaluated through the study of SiO_2 layers in MOS structures. The results of the new test correlated well with the simulation of the radiation effects achieved by cobalt-60 ionizing radiation. The technique is potentially suitable for wafer level testing at production facilities.

- The work on the triple-product convolver (TPC) has been one of the most favorably evaluated ILIR programs. Accomplishments this year include the integration of the TPC system, which can process the outputs from 16 laser beams—twice the number previously possible—in about 60 μs. This result is equivalent to performing an 8-point discrete Fourier transform in the same time.

- The ILIR project on subaural acoustic signal transmission and processing offers a potential solution to a military communications problem. The approach is to use a fluidic medium to transmit acoustic signals which cannot be easily intercepted or interfered with. Low-frequency signals (infrasonic—less than 15 Hz) are easily produced and transmitted. The feasibility of the concept was demonstrated in our laboratories.

AH44. The AH44 basic research program continued the prior concentration in the four main areas of fluidics, ordnance electronics, nuclear weapons effects, and near-millimeter-wave research. The general objective of HDL's AH44 program is to increase the technology base for military applications—especially those related to intelligence, surveillance, and target acquistion (ISTA)—in the four areas. Several of the tasks have matured from AH44 to AH25 or AH18, indicating that the programs, while fundamental in nature, have real potential for solving military problems. Program output for the year can also be measured in terms of outside publications (38), HDL reports (15), patents (20), and presentations to professional societies (33).

Some of the FY79 contributions of the AH44 program follow.

- A breakthrough was achieved in the analysis of the high-frequency eigenmodes in the fluidic laminar proportional amplifier, making it possible to predict the resonant peaks. Also, an order of magnitude improvement was made in reducing null offset in fluidic components through the use of negative feedback circuits.

- Research in dielectrics showed that the field and dose dependencies for interface-state buildup were similar in both wet and dry oxide capacitors. Also, a phenomenological model of the two-stage process for interface-state buildup has been developed. The model gives the mathematical dependencies of the buildup on time, field, temperature, and dose.

- Work on the acousto-photorefractive memory correlator led to the discovery of the acousto-photorefractive effect in lithium niobate. It was also found that the effect is due to surface charge and that fast erasure can be achieved through simple surface treatments.

- A conventional flash x-ray machine (FX-45) was operated in a thin-foil, multiple-pass, bremsstrahlung converter mode, resulting in a factor of three dose enhancement compared to the normal mode. Also, a low-impedance relativistic electron-beam generator (1 MeV, 150 kA, 100 ns) was designed and constructed in collaboration with the University of Maryland's Electron Ring Accelerator Laboratory.

- Near-millimeter-wave (NMMW) lasers were investigated for use as stable, highly coherent radiation sources. Laser action was obtained on three new molecular gases (methyl fluoride-d_3, chlorodifluoromethane, and ethyl iodine). Through the use of these gases, 20 new lasing lines with wavelengths ranging from 0.16 to 1.49 mm were found.

- Ultra-high-resolution IR spectroscopy on NMMW laser gases was performed using new measurement techniques developed at HDL. Molecular constants for the gas 1,1-difluoroethylene were determined, and NMMW laser lines were assigned. Published data for another gas, CD_3F, were analyzed, and predictions that it would be an efficient NMMW laser gas were verified.

- Investigations of other NMMW sources were carried out for solid-state and electron-beam devices. Optical control of a 70-GHz pulsed IMPATT diode using GaAs-laser diode emission was demonstrated. Analysis and design of a 3.5-kW, 240-GHz gyrotron oscillator were completed and preparations made for construction of the oscillator. The basic theory of another electron-beam source, the orotron, was investigated, and the design of a 70-GHz oscillator was completed. Fabrication of the orotron oscillator was essentially completed, and cold testing of the device was begun.

- Novel NMMW detection techniques were investigated by the use of HgCdTe. Using this alloy semiconductor allowed hot-electron photodetection of NMMW radiation to be observed for the first time over the wavelength range from 0.1 to 4.0 mm.

- In the NMMW antenna program, several dielectric rod antennas were designed and tested. Also, three types of slotted-waveguide arrays were designed, built, and tested. The design technique involved scaling practical microwave antennas down to NMMW frequencies. Measurements verified that the procedure was valid.

AH25. The AH25 program includes all exploratory development (6.2) work (except for fuzing). The projects are divided into three areas: near-millimeter-wave technology, fluidic technology, and nuclear weapons effects. The overall program forms a bridge between the corresponding aspects of the research program and eventual systems programs.

Near-Millimeter-Wave Technology. Current efforts in the NMMW portion of the spectrum (100 to 1000 GHz) are directed toward providing the Army with the capability for operating under all visibility conditions. NMMW systems can operate in realistic battlefield environments where there are obscurants such as fog, smoke, and dust; the performance of electro-optic and infrared systems, in contrast, degrades under similar circumstances. In addition, NMMW systems provide improved resolution, smaller size, and better electronic-countermeasure protection than most microwave systems.

The NMMW technology program began in FY79. The design and construction of an NMMW mobile measurement facility (MMF) under a contract with the Georgia Institute of Technology (begun under the AH44 program) proceeded on schedule. The MMF will provide a much-needed data base on transmission, target, and clutter/ background signatures in realistic battlefield environments at 94, 140, and 220 GHz. This very important program was the direct outgrowth of a recommendation of the NMMW Technology Base Study Panel, a 50-member blue-ribbon committee which was chaired by two members of the HDL staff during 1977. An investigation of NMMW measurement standards was begun, with inital emphasis on making accurate measurements at 240 GHz. An elementary system for the measurement of multipath effects at 94 GHz also was designed and built. The system will be used to determine possible effects of multipath signals on tactical ground-based NMMW radars. HDL coordinated NMMW programs in all the ERADCOM laboratories, as part of this program.

Fluidic Technology. Fluidics has been hampered since its inception by the fact that it is simple in concept but difficult in application. Only in the past five years have acceptable mathematical models existed for fluid amplifiers. Each of the last five years has seen improvement in both the mathematical models and the performance of the laminar proportional amplifier (LPA). As a result, linearity of output has been increased and noise generated within the amplifier has been reduced. This has extended the dynamic range of fluidic control systems beyond 5000 and has lowered the pressure threshold which can be fluidically detected. These improvements enabled the following major contributions.

- The most significant event in fluidic development in FY79 was the successful demonstration of a stabilization system for the main gun of an armored combat vehicle. The demonstration, conducted in April 1979 on an M48A5 tank, showed that the fluidic system met the performance requirements of the current field system used on the M60A1 tank. In the fluidic system, a laminar jet angular rate sensor (LJARS) senses gun or turret rotation. The LJARS output is amplified by staged LPA's, and frequency response is controlled to avoid driving resonances in the system. A servovalve is then driven by this amplified signal to operate hydraulic actuators, which rotate the gun or turret to compensate for motion of the tank. If fluidics were used on gun turrets, the initial cost and maintenance costs would be reduced, reliability, availability, and durability would be increased, and susceptibility to electromagnetic interference would be avoided.

- A fluidic temperature sensor has been demonstrated to be capable of continuously measuring temperature to 1650°C (3000°F). The response time of the fluidic sensor was observed to be significantly less than that of a shielded thermocouple, normally used to control industrial ovens. During FY79, the first one-piece temperature probes were designed and fabricated of three different materials. Five complete fluidic temperature-sensing systems have been built for industrial service. These fluidic temperature sensors have significant potential for the control of high-temperature processes; such applications could result in significant energy savings.

• Extensive research in FY79 achieved significant improvements in the LJARS used in combination with the LPA. As a result, angular rates down to 0.002 degree per second—one-half the earth's rate of rotation—were successfully measured. This advance will make the LJARS/LPA system a candidate for future low-cost autopilots for missiles and remotely piloted vehicles.

Nuclear Weapons Effects. The nuclear weapons effects area provides the technology to assure the survivability of critical Army material in a nuclear engagement. The emphasis in FY79 was on vulnerability assessment and development of hardening techniques. Major contributions of this program in FY79 include the following.

• HDL conducted the first partial simulation of the endoatmospheric electromagnetic pulse (EMP) environment using the AURORA Flash X-Ray Facility augmented with a large parallel-plate transmission line. This experimental arrangement was used to simulate the response of several antenna structures and the AN/PRC-77 single-channel man-pack radio. These tests also used a fiber-optic data-transmission system and field sensor (invulnerable to radiation) developed by HDL during early 1979. The tests demonstrated that, over a few meters, the important features (including conductivity) associated with the endoatmospheric EMP environment can be partially reproduced. The test also confirmed several analytical prediction methods used to calculate the response of monopole antennas to endoatmospheric EMP.

• The susceptibility and survivability of fiber-optic communications cables and associated system components are being investigated. A major effort in FY79 was directed to developing hardening approaches that will provide the means of producing fiber-optic cables that are hard to all nuclear effects. The doped-silica fiber-optic cables are inherently hard to EMP and much lighter than normal electrical cables, but they exhibit significant susceptibilities to nuclear and thermal radiation levels that Army tactical equipment must survive. The losses induced in doped-silica fiber-optic cables from nuclear radiation depend on temperature, dose, and dose rate. Phosphorus was added to suppress the temperature dependence of the transient losses in the doped-silica fibers. GeO_2-SiO_2 fibers containing no boron could be useful in initial tactical radiation environments where the radiation is delivered in about 10 s and low-temperature operation is required. HDL and CORADCOM are using the results of this program as a basis for choosing the best radiation-resistant optical fiber for use in future Army production of fiber-optic communication cables. Serious nuclear thermal radiation effects were also found in polyurethane-jacket fiber-optic cables at fluences as low as 30 cal/cm^2. The exposure of these cables in thermal-blast field tests produced significant reduction in the mechanical strength of the cables from the thermal radiation, making them very susceptible to catastrophic damage from the blast wave which closely follows the thermal pulse. A dramatic increase in damage threshold was achieved by adding aluminum foil and Teflon tape layers under clear Teflon jackets. With this hardening technique, cables survived 180 cal/cm^2.

AH18 Fuze Technology. As the principal participant in the development of fuzes and the technology base for fuzing, HDL was also active in the management of these efforts. The five-year plan prepared by HDL in FY78 was revised in FY79 to reflect changing priorities.

Major accomplishments of the fuze technology program during FY79, given below, will contribute to improving the effectiveness of air-defense and shaped-charge munitions and to reducing the cost of field artillery.

• Encounter analysis has shown the value of digital signal-processing techniques which will be applied in future, more ECM-resistant, "smarter" proximity fuzes.

• Electrostatic signatures were obtained for projectiles fired near a charged body. These signatures were essentially as predicted, except that a large signal was observed at muzzle exit. Delayed arming would avoid the prefires experienced by other experimenters.

ARO and IR&D Support. As part of their efforts to maintain an active relationship with the rest of the R&D community, the scientists and engineers involved in technology base programs review proposals from academia to the Army Research Office (ARO), as well as reports from industry on Independent Research and Development (IR&D) programs.

During FY79, HDL scientists reviewed more than 180 research proposals for ARO. This association with ARO and the basic research community is considered valuable to HDL because it is one of the ways in which HDL remains informed about current research relevant to the needs of the Army. Often the HDL reviewers become affiliated with the proposed research either by requesting scientific cognizance status (60 such requests were made this year), or by requesting the more intensive involvement of scientific liaison status (21 such requests this year).

HDL also evaluated 664 IR&D proposals, and participated in five on-site reviews. Conversations with principals often led to innovations and were mutually beneficial.

technology transfer

The Military-Civilian Technology Transfer Program of the Harry Diamond Laboratories (HDL) seeks to use the resources of the Laboratories to identify and apply existing technology—knowledge, facilities, or capabilities—to problems faced by federal civilian agencies, state and local governments, and the private sector. Technology transfer also involves managing the adaptation of relevant existing technology toward the solution of the given problems in the face of organizational barriers.

HDL's program to increase the rate and effectiveness of the transfer of its mission-developed technology began early in 1974, as an internally initiated experiment; HDL formalized its program by joining a consortium of 30 DoD laboratories in August of that year. This consortium subsequently became the Federal Laboratory Consortium (FLC) for Technology Transfer, with over 190 participating laboratories and many national programs coordinated by the National Science Foundation. The representatives of the FLC laboratories form a network for the exchange of information and cooperate continually to develop policies and procedures to overcome common barriers to effective technology transfer.

The HDL technology transfer program includes three major kinds of activities. (1) The program provides prompt responses to requests for information regarding technology (regardless of the source of the technology). This "technology brokerage" is an important component of the program, especially relative to state and local governments. (2) The program identifies civilian sector problems which might be solved through HDL technology and, in special cases, develops funded projects to address these problems by adapting the technology. (3) The HDL program provides significant support to the regional and national activities of the FLC as it achieves greater visibility and provides more service. This person-to-person interaction and procedural flexibility is important for effective technology transfer; this is well documented and emphasized in the Army regulation (AR 70-57) concerned with the program.

Military-Civilian Technology Transfer Report, FY79 (RCS CSCRD-1720)

This is the fourth report of HDL technology transfer activities provided pursuant to Army Regulation 70-57 and summarizes major activities occurring during FY79.

The significant activities presented in this summary are divided into three categories as follows.

- Information or assistance provided in response to an inquiry
- Transfer initiatives by HDL
- Activities with the Federal Laboratory Consortium

Funded projects which resulted from any of the contacts are presented in table 1, which shows the relevant project data. All these projects were funded entirely by a civilian agency sponsor; no cooperative projects were undertaken during the reporting period. The direct labor committed to these projects equalled 3.6 man years during FY79.

About 180 inquiries were received during the year. Many inquiries for information required only sending an existing report, giving a direct answer, or providing one referral to obtain a direct answer; these had no follow-up and have not been regularly recorded. Such inquiries are not presented as examples in this report, although about 65 percent of the total number of inquiries received fall in this group. Experience during the year continues to show that an identified source of information is needed for these simple "transfers."

Responses to Requests for Information and Assistance. The following are brief descriptions of responses made to a few of the significant inquiries during the reporting period. They reflect the diversity of the technical areas covered and the range of requestors to whom assistance was provided.

- Information and assistance was provided on the availability of a special all-terrain vehicle for a handicapped person who liked the outdoors, on diagnosing true senility in the aged, and on choosing an appropriate artificial larynx for an aged cancer victim.

- Technical information and advice was found to aid staff members of the Red Cross Blood Research Laboratory in the design of a better bloodmobile.

- Aid in planning and evaluating energy alternatives was arranged for the City of Rockville, MD, and for the Maryland State Energy Office.

- Technical information was provided to many municipal governments on such topics as the potential interference of a theft prevention device with heart pacemakers, birds as potential disease carriers, the removal of grafitti from public buildings, and sludge disposal.

- Technical assistance was provided to the Delaware Technical and Community College in planning their expanding use of computers, and ar-

Table 1. Technology Transfer Projects for FY79

Projects	Sponsor	Science and technology areas	Man years	Funding[a] ($K)
Stream bed profiler	US Geological Survey	Lasers	0.10	10
OCS R&D assessment	US Geological Survey	All	0.05	(30)
Communicator	US Geological Survey	Communication electronics	0.27	(23.9)
Flowmeter	US Geological Survey	Fluidics	0.20	(20)
Mud-pulse telemetry	US Geological Survey	Fluidics	2.30	100 (100)
Gas sensor	US Geological Survey	Fluidics	0	(150)
Improved aircraft antenna	Federal Aviation Administration	Antenna design	0.35	74.3
Standard photomask fabrication	National Bureau of Standards	Semiconductor device fabrication	0.14	9.9
Electronic device fabrication	US Postal Service	Thick-film hybrid fabrication technology	0.21	19.1

[a]*Amounts in parentheses represent funds carried over from previous year.*

rangements were made to save valuable George Mason University library material from being destroyed by mold.

- Information on technology available from the government was provided to a number of small companies.

Transfer Initiatives. The following are brief descriptions of a few of the contacts initiated by HDL where it was thought that HDL technology might contribute to the program needs of a civil agency. Also mentioned here are activities in which HDL participated in order to publicize the HDL technology transfer program.

- In order to promote technology transfer, the HDL technology transfer representative attended the National League of Cities Meeting, the National Information Conference and Exposition, and the University Public Service and Research Association Meeting.

- HDL technology was presented at the Minority Business Technology Commercialization Conference in Boston, and HDL participated in the Philadelphia Technology and Business Opportunity Conference and a Northeastern Technology Transfer Conference sponsored by Congressman Dodd of Connecticut.

- Contacts to discuss fluidics were initiated with the Nuclear Regulatory Commission and the National Bureau of Standards, where new standard temperature-measuring methods may result.

- A brochure on the HDL Technology Transfer Program and another on HDL technology were published and distributed at conferences during the year.

- A tour and a presentation of resources available for finding scientific and technical information were proposed and arranged for members of the Delmarva Library Consortium.

Activities with Federal Laboratory Consortium. The following are brief descriptions of some significant activities of the HDL representative in support of the Federal Laboratory Consortium for Technology Transfer and within the US technology transfer community.

- On behalf of the FLC, HDL arranged for informal participation in the Consortium by the Johns Hopkins Applied Physics Laboratory.

- The HDL representative proposed a reorganization of the FLC for improved referral of complex information requests; the new resource organization will be implemented and managed by him.

- Participation on the FLC National Executive Committee and its Planning Subcommittee as well as the Mid-Atlantic Regional Executive Committee continued thoughout the year.

- An article on the FLC as a resource was drafted for a National Institutes of Health newsletter, the Research Resources Reporter.

- The HDL Technology Transfer Coordinator represented the FLC in the Federal Regional Council Meetings with Maryland and the District of Columbia, as well as in discussions with several agencies such as the Consumer Product Safety Commission and the Food and Drug Administration.

- Papers, grant proposals, and proposed plans have been reviewed for various segments of the Technology Transfer community.

Assessment of the Program. With the continually growing concern for urban problems and a need for increased productivity in local units of government, the program of technology transfer from Army laboratories clearly enhances the Army's image as a continuing contributor to the community. The Army also benefits from technology transfer by the increased growth of technology needed by the Army; the development of civilian applications and markets promotes private research and innovation which can feed back into better technology for the Army.

Representatives of state and local governments have been observing the technology transfer

program to see if the federal government is really going to make available the needed resources. It appears that the Army could enhance its program if further resources were committed and a definite statement of policy support were provided to the laboratories.

The political desirability and economic value of the program were attested during this past year by many letters and statements from state and local government representatives on the value of technology transfer and assistance from the federal laboratories.

Although AR 70-57 provides sufficient guidelines for the operation of the Technology Transfer Program, it does not insure resources for the program; indeed, these resources have eroded this year. This is a direct effect of manpower cutbacks and the lack of a strong indication that technology transfer is part of the laboratory mission. It should be emphasized that the 3-percent involvement specified by the regulation is a goal rather than a limit.

In order to be truly effective, the Army program now needs a strong statement that technology transfer is part of the mission of every laboratory, that 3 percent of the technical manpower involved is an appropriate goal, and that every laboratory should participate in the Federal Laboratory Consortium. In addition, some funds and manpower allocations should be made available for technology transfer activities principally with state and local governments. This additional support would allow the program to be consistently responsive to state and local representatives who are becoming increasingly vocal political constituents.

small business utilization

The FY79 small business program at HDL was the largest in history as a result of HDL's assumption of procurement responsibilities for the Signals Warfare Laboratory (SWL). These additional responsibilities resulted in the award of $209,571,133 to both large and small business concerns. Small firms received awards amounting to $14,324,389 or 7 percent of the total dollars available. The assigned small business awards goal was $9,000,000. Therefore, HDL exceeded its FY79 goal by $5,324,389, or 59 percent.

In total small business set-aside actions, where competition is limited to only small firms, there were 47 awards in FY79 compared to 42 in FY78. However, the dollars awarded decreased slightly in FY79, to $1,239,132, compared to FY78 awards of $1,274,581. The FY79 objective of $2,327,000 was not accomplished.

Under the Small Business Administration (SBA) section 8(a) program, wherein awards are made to SBA-certified-eligible socially and economically disadvantaged small concerns on a noncompetitive basis, there were four awards amounting to $109,961 in FY79 compared to three awards in FY78, which amounted to $305,779. The FY79 section 8(a) objective of $500,000 was not achieved.

Direct awards to socially and economically disadvantaged small business firms on a competitive basis in FY79 amounted to $268,260, as a result of 69 awards. Thus, the performance in this area surpassed the assigned goal of $250,000.

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patents issued

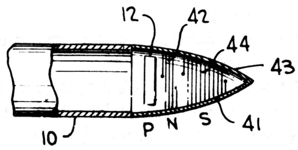
4,164,905
LUMPED NEUTRALIZATION COIL ARRANGEMENT FOR INDUCTANCE FUZE

Hans W. Kohler, Sarasota, Fla., and Helmut Sommer, Bethesda, Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.

Filed Dec. 22, 1971, Ser. No. 211,140

Int. Cl.² F42C *13/08, 19/00*

U.S. Cl. 102—212 **5 Claims**



1. An inductance proximity fuze comprising:
(a) A primary coil;
(b) Means for applying current to said primary coil to establish a magnetic field having an infinite number of field lines;
(c) A passive secondary coil having a first number of turns and disposed relative to said primary coil such that said first number of turns are traversed by a first portion of said field lines;
(d) A passive neutralizing coil having a second number of turns connected in series opposition to said secondary coil and disposed relative to said primary coil such that the second number of turns are traversed by a second portion of said field lines and such that under free space conditions the product of said first portion of field lines and said first number of turns is approximately equal to the product of said second portion of field lines and said second number of turns; said primary, secondary, and neutralizing coils being wound symmetrically about a common axis which coincides with the longitudinal axis of said proximity fuze;
(e) Means connected to said secondary coil and said neutralizing coil for detecting any voltage differences induced therein by magnetic field disturbance of said free space magnetic conditions; and
(f) Means for initiating operation of a fuze in response to a predetermined voltage difference existent across said secondary coil and said neutralizing coil.

4,165,503
HYDROSTATIC SEISMIC SENSOR

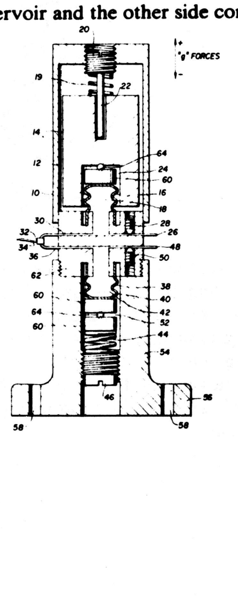
Allen B. Holmes, Rockville, and Stacy E. Gehman, Takoma Park, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.

Filed Dec. 9, 1977, Ser. No. 858,983

Int. Cl.² G01V *1/16*

U.S. Cl. 340—17 R **5 Claims**

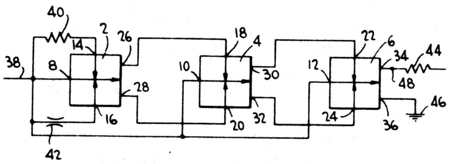
1. A hydrostatic seismic accelerometer comprising:
a housing including a first interior chamber;
a sensing mass in said first chamber, said sensing mass having first and second coaxial cavities;
an alignment pin attached to said housing and extending into said first cavity for maintaining the alignment of said sensing mass;
a first flexible closed reservoir, containing a sensing fluid, extending into said first chamber and into said second cavity to support said sensing mass;
a first spring encircling said alignment pin and biasing said sensing mass against said first reservoir;
a mounting base connected to said housing, said base having a second interior chamber;
a second flexible closed reservoir, containing a sensing fluid, extending into said second chamber;
a second spring biased against said second reservoir;
a differential pressure transducer having one side connected to said first reservoir and the other side connected to said



second reservoir; and valve means for venting said second reservoir to the atmosphere.

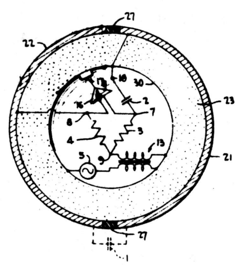
4,164,961
FLUIDIC PRESSURE/FLOW REGULATOR
Tadeusz M. Drzewiecki, Silver Spring, and Francis M. Manion, Rockville, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jul. 28, 1977, Ser. No. 819,786
Int. Cl.[2] F15C *1/14*
U.S. Cl. 137—823 **7 Claims**

1. A fluidic flow regulator comprising:
a fluid inlet for connection to a source of unregulated fluid;
power jet means comprising a plurality of channels communicating with said fluid inlet, said channels being oriented to issue streams of fluid that converge to form a jet of fluid, the flow resistance of the first of said channels having a generally linear flow rate versus pressure drop characteristic and the flow resistance of the second of said channels having a flow rate that varies approximately as the square root of the pressure drop, to provide a jet of



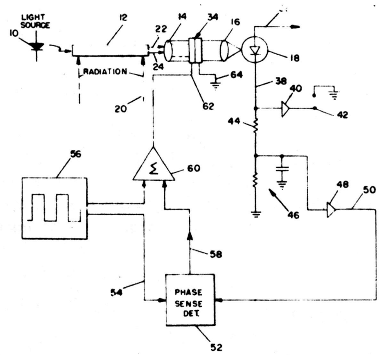
fluid whose direction varies solely as a function of the pressure of said unregulated fluid; and
output means to divide said jet of fluid into a discharge stream and a regulated stream, said output means being positioned to increase the proportion of said jet of fluid going to said discharge stream as the presssure of said jet of fluid increases.

4,163,423
PROXIMITY FUZE
Hans W. Kohler, Washington, D.C., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Apr. 18, 1962, Ser. No. 189,250
Int. Cl.[2] F42C *13/00*
U.S. Cl. 102—211 **11 Claims**



4. In a projectile comprising a casing having a first electrically conducting part, a second electrically conducting part and an electrically insulating part interposed between said first and second conducting part, a proximity detector comprising:
(a) a bridge circuit;
(b) said bridge circuit having a first terminal connected to said first electrically conducting part of said projectile casing; and
(c) said bridge circuit having a second terminal adjacent to said first terminal and connected to said second electrically conducting part of said projectile casing.

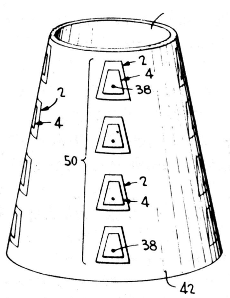
4,164,650
MEANS FOR REDUCING NUCLEAR RADIATION-INDUCED FLUORESCENCE NOISE IN FIBER-OPTICS COMMUNICATIONS SYSTEMS
James C. Blackburn, Adelphi, and Alan Bromborsky, Beltsville, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jul. 8, 1977, Ser. No. 814,019
Int. Cl.[2] H04B *9/00*
U.S. Cl. 250—199 **6 Claims**



1. An optical filtering apparatus for a light communication system comprising:
a light source having a center communication frequency subject to frequency drift;
optical fiber means having a first end thereof located adjacent the light source, the length of the optical fiber means being subjected to externally impinging energy which generates noise in the fiber means;
a tunable optical filter located at the second end of the optical fiber means for filtering a light source signal and rejecting the noise, the filter having electrical input means for varying a center frequency of the filter;
photodetection means located at an output of the filtering means for converting the filtered light signal to an electrical signal; and
tuning circuit means responsive to the center frequency of the light source for shifting the center frequency of the filter to coincide with that of the center frequency of the light source, the tuning circuit means having an input connected to the photodetection means and having an output connected to the electrical input means.

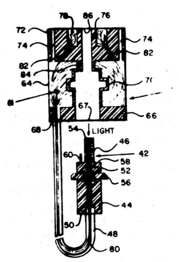
4,162,499
FLUSH-MOUNTED PIGGYBACK MICROSTRIP ANTENNA
Howard S. Jones, Jr., Washington, D.C.; Frederick G. Farrar, Kensington, and Daniel H. Schaubert, Silver Spring, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Oct. 26, 1977, Ser. No. 845,528
Int. Cl.[2] H01Q *1/38, 1/28*
U.S. Cl. 343—700 MS **10 Claims**

1. A piggyback radiating system which comprises: p1 a ground plane;



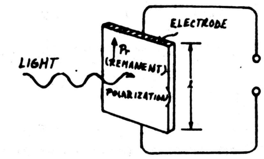
a first radiating element which is flush mounted above the ground plane;
a second radiating element which is flush mounted over the first radiating element in an area where there is minimal current flow;
a first coaxial feed means for feeding the first radiating element; and
a second coaxial feed means for feeding the second radiating element, the outer conductor of the second feed means shorting the ground plane and the first radiating element, therefore serving as an impedance match to the first radiating element.

4,161,348
PREASSEMBLED FIBER OPTIC SECURITY SEAL
Reinhard R. Ulrich, Rockville, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Aug. 9, 1977, Ser. No. 823,077
Int. Cl.² G02B *5/16*
U.S. Cl. 350—96.20 **10 Claims**



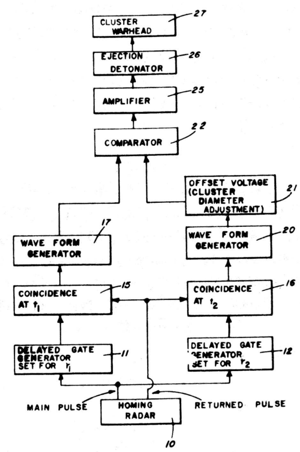
1. A preassembled fiber optic seal comprising:
a fiber optic bundle;
a first connector for securing the outward ends of the bundle together, whereby individual fibers of the bundle are randomly positioned within the connector;
a second connector having an intermediate length of individual fibers wrapped therearound;
means for permanently securing the first connector to the second connector;
an opening formed in the second connector, the opening positioned in registry with the ends of the bundle when the connectors are secured together;
wherein light passage through the fiber optic bundle creates a unique fingerprint at the second connector opening, which will be altered if the seal is broken.

4,160,927
FERROELECTRIC CERAMIC DEVICES
Philip S. Brody, Brookmont, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Division of Ser. No. 533,365, Dec. 16, 1974, Pat. No. 4,051,465, which is a continuation-in-part of Ser. No. 411,853, Nov. 1, 1973, Pat. No. 3,855,004. This application Apr. 5, 1977, Ser. No. 784,761
Int. Cl.² G21D *7/00*
U.S. Cl. 310—302 **2 Claims**



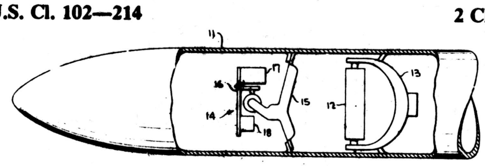
1. An electrical battery apparatus comprising,
a substrate of a radioactively ionized polycrystalline ferroelectric ceramic material disposed between two conductive electrodes, and
electrical means for remanently polarizing said substrate in a predetermined direction.

4,159,476
EJECTION FUZE
Hans W. Kohler, Washington, D.C., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Aug. 19, 1954, Ser. No. 451,077
Int. Cl.² F42C *13/04*
U.S. Cl. 343—7 PF **8 Claims**



1. An ordnance fuze adapted to function at a predetermined time interval in advance of predicted missile-target intercept, said fuze comprising: means for sensing missile-to-target distance; means for initiating the generation of a first waveform voltage when the missile reaches a first predetermined distance from the target; means for initiating the generation of a second waveform voltage when the missile reaches a second and shorter predetermined distance from the target; comparator means for comparing two voltages and producing a comparator output signal when the two voltages being compared become equal; a source of constant direct-current offset voltage interposed between one of said first and second waveform voltages and said comparator means; means for applying the other of said first and second waveform voltages to said comparator means; and means for utilizing said output signal from said comparator means to function the fuze.

4,157,685
WARHEAD FUZE SEEKER
Harry L. Gerwin, Bethesda, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Nov. 9, 1965, Ser. No. 507,639
Int. Cl.² F42C *13/04*
U.S. Cl. 102—214 **2 Claims**

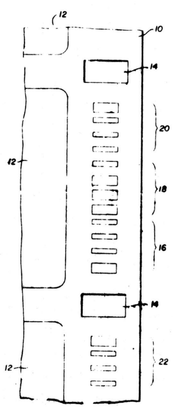


1. In a medium range interceptor missile for deployment against air supported targets, said missile having a directional blast fragmentation warhead fuze seeker system comprising a gimbaled system for supporting and positioning the warhead within the nose section of the missile and a proximity fuze seeker system which senses the intended target, controls the gimbaled system through a servo system whereby the axis of the fragmentation blast pattern of the warhead is aligned with the line-of-sight from the interceptor missile to the target, and fires the warhead when the interceptor missile is a predetermined distance from the target, the improvement comprising:

(a) a copper-plated, plastic foam waveguide antenna permanently mounted forward of the warhead and connected to the proximity fuze seeker system for radiating and receiving electromagnetic energy in the direction of the target, said antenna having a sufficiently low density as not to degrade the functional performance of the warhead thereby obviating the necessity of removing said antenna prior to firing the warhead, and

(b) the remaining high-density components of the proximity fuze seeker system being mounted aft of said warhead within the missile.

4,150,882
IDENTIFICATION CODE GENERATOR FOR HIGH SPEED MOTION PICTURE PHOTOGRAPHY
William L. Konick, 1111 University Blvd. W., Silver Spring, Md. 20902, assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Oct. 29, 1976, Ser. No. 736,979
Int. Cl.² G03B *17/24*
U.S. Cl. 352—39 **10 Claims**



1. In the combination of a movie camera having a light source for recording information by a single light beam on a film edge and a code generator for driving said light source, the improvement being in said code generator which comprises:

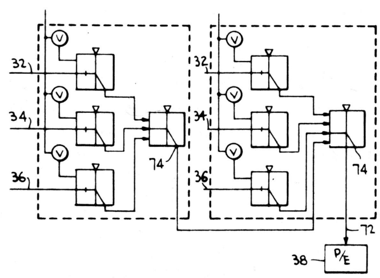
input means for producing a serial binary code signal of N bits, where N is greater than six;

a pulse width means for generating a variable pulse width representing a logic zero or a logic one in response to said code signal;

output means for driving said light source; and

control means connected to said input and pulse width means for causing the signal to be transferred from said input means to said output means through said pulse width means at a rate sufficiently greater than the speed of said film to record all N bits on the edge of a sngle frame of said film in a serial sequence.

4,144,906
PROGRAMMABLE FLUIDIC PRESSURE-TO-ELECTRONIC INTERFACE SYSTEM
Maurice F. Funke, Columbia, Md., and John M. Goto, Falls Church, Va., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jul. 14, 1977, Ser. No. 815,624
Int. Cl.² F15C *1/12*
U.S. Cl. 137—819 **4 [illegible]ms**



1. A programmable fluid logic module for providing an interface between a plurality of fluid input signals and a pressure-to-electric transducer comprising:

a plurality of first fluidic logic devices each having first and second input channels for receiving first and second inputs and an output channel producing an output signal only when said first and second inputs are not the same and producing no output signal when said first and second inputs are the same;

first connecting means for connecting each of said first input channels to a source of supply fluid;

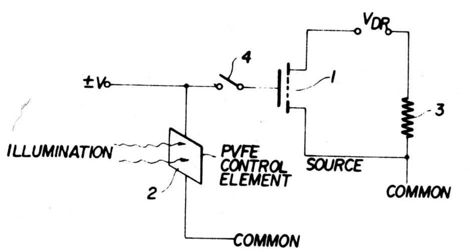
second connecting means for providing input signals to each of said second input channels;

a second fluidic logic device having a plurality of input channels and an output channel which produces an output signal only when any of said plurality of input channels of said second logic device receives an input signal; and

third connecting means for connecting each one of said output channels of said first logic devices to one of said input channels of said second logic device.

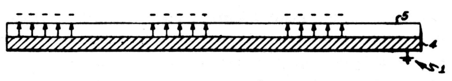
4,144,591
MEMORY TRANSISTOR
Philip S. Brody, Brookmont, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Continuation-in-part of Ser. No. 824,894, Aug. 15, 1977, Pat. No. 4,051,465, which is a continuation-in-part of Ser. No. 533,305, Dec. 24, 1974, Pat. No. 3,855,004. This application Apr. 5, 1978, Ser. No. 893,567

Int. Cl.² G11C *11/22, 11/42*
U.S. Cl. 365—228 **8 Claims**



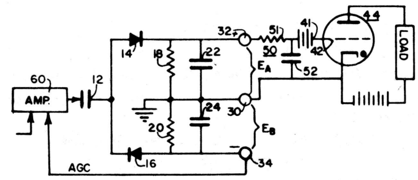
1. A memory transistor comprising,
a solid state switch means capable of assuming one of two states dependent on the polarity of a bias signal which is to be applied thereto,
a photovoltaic-ferroelectric means for storing information regarding the polarity of said bias signal, which information is stored in the form of a remanent polarization in one of two possible directions,
illumination means for illuminating said photovoltaic-ferroelectric means when it is desired to generate said bias signal, and
means for applying said generated bias signal to said solid state switch means.

4,139,908
PHOTOVOLTAIC-FERROELECTRIC DATA RECORDER
Philip S. Brody, Brookmont, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Continuation-in-part of Ser. No. 533,365, Dec. 16, 1974, Pat. No. 4,051,465, which is a continuation-in-part of Ser. No. 411,853, Nov. 1, 1973, Pat. No. 3,855,004. This application Aug. 15, 1977, Ser. No. 824,894
Int. Cl.² G11C *11/42*
U.S. Cl. 365—117 **14 Claims**



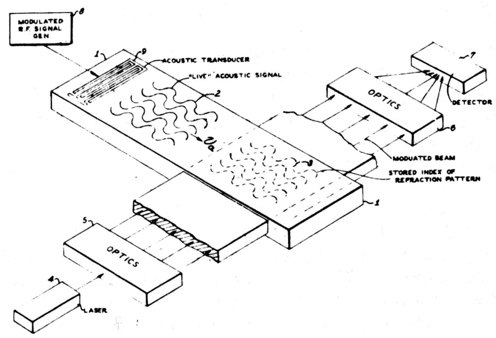
9. An information storage and read-out apparatus comprising,
a plurality of cells of ferroelectric ceramic material, each cell being remanently polarized,
means for illuminating said cells, each cell thus producing a photovoltaic voltage,
means for parallel-transferring the voltage produced by each cell to the stages of a register means, and
means for serially reading out the contents of said register means.

4,140,062
DIFFERENTIAL INTEGRATOR
Paul M Tedder, Gainesville, and Ovid R. Gano, Melrose, both of Fla., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Feb. 16, 1955, Ser. No. 488,736
Int. Cl.² F42C *11/00*
U.S. Cl. 102—219 **6 Claims**



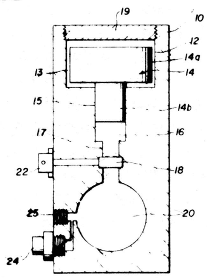
1. A differential integrator circuit comprising: an input capacitance; means for applying an a-c input signal of varying amplitude between one terminal of said capacitance and circuit ground; first and second resistances each having one terminal connected to circuit ground; first and second capacitances connected across said first and second resistances respectively, said second capacitance being larger than said first capacitance; first and second diodes connected between the other terminal of said input capacitance and the ungrounded terminals of said first and second resistances respectively, said diodes being connected with opposite polarities; means for taking a first unipotential output signal from across said first resistance; and means for taking a second unipotential output signal from across said second resistance.

4,139,277
ACOUSTO-OPTIC MEMORY CORRELATOR
Norman J. Berg, Baltimore, Md.; Bob L. Smith, deceased, late of Huntsville, Ala. by Allen B. Adams, legal representative, Cupertino, Calif., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jun. 7, 1977, Ser. No. 804,206
Int. Cl.² G02F *1/11*
U.S. Cl. 350—358 **6 Claims**



1. An acousto-optic apparatus for providing the correlation of a first signal and a stored signal, comprising,
an acousto-optic interaction medium having said stored signal stored therein as a spatially varying index of refraction pattern,
said medium having an acoustic transducer means for converting an electrical signal to an acoustic signal disposed thereon to one side of said spatially varying index of refraction pattern,
means for applying a high-frequency A.C. signal to said transducer means, said signal having an envelope corresponding to said first signal,
laser means directed to transmit a laser beam across said medium at the area of said stored index of refraction pattern and across the path of said acoustic signal in said medium, and
detector means for detecting said laser beam after it traverses said acousto-optic interaction medium,
whereby said detector means produces a signal representative of the correlation of said first signal and said stored signal.

4,138,893
HYDROSTATIC ACCELEROMETER
Allen B. Holmes, Rockville, and Stacy E. Gehman, Takoma Park, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Dec. 9, 1977, Ser. No. 858,982
Int. Cl.² G01P *15/08*
U.S. Cl. 73—516 LM **6 Claims**

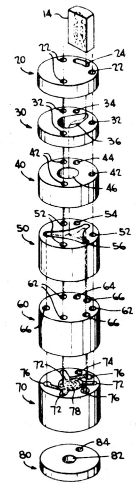


1. A hydrostatic accelerometer for the measurement of "*g*" forces comprising:
- a housing member including a first interior chamber and a second interior chamber;
- a differential pressure transducer situated between and separating said first and second interior chambers;
- a sensing mass in said first interior chamber comprising a solid sensing mass and a liquid sensing mass, said liquid sensing mass abutting said differential pressure transducer;
- a low density fluid in said second interior chamber; and
- means for adjusting the pressure in said second chamber.

4,139,849
DOPPLER FUZING SYSTEM HAVING A HIGH RESISTANCE TO NOISE AND JAMMING
Paul M. Tedder, Gainesville, Fla., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Sep. 3, 1954, Ser. No. 454,236
Int. Cl.² F42C *13/04*
U.S. Cl. 343—7 PF **3 Claims**

1. An electronic ordnance fuze responsive only to a signal of increasing amplitude applied for at least a predetermined minimum time, said fuze comprising: means for radiating radiofrequency energy, receiving a portion of said radiofrequency energy after reflection from a target, and mixing the radiated and reflected energy to obtain a Doppler-frequency alternating current signal of increasing amplitude as the fuze approaches the target; means for amplifying said alternating current signal; rectifier and filter means for obtaining from the amplified alternating current signal a first unipotential signal proportional to its envelope; differentiator means connected to said rectifier and filter means for obtaining a second unipotential signal which is proportional to the rate of change of said first unipotential signal; limiter means connected to said differentiator means for limiting the amplitude of the output of said second unipotential signal; and an integrator and trigger circuit to which said second unipotential signal is fed, said circuit producing a pulse which initiates detonation when said second unipotential signal has at least a predetermined minimum amplitude for at least a predetermined minimum time.

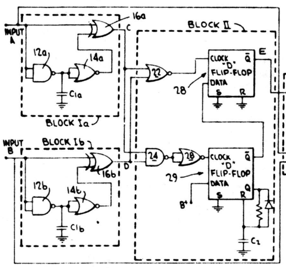
4,134,100
FLUIDIC MUD PULSE DATA TRANSMISSION APPARATUS
Maurice F. Funke, Columbia, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Nov. 30, 1977, Ser. No. 855,863
Int. Cl.² G01V *1/40*
U.S. Cl. 340—18 LD **5 Claims**



1. Telemetry apparatus for transmitting data from sensors to the surface during the drilling of a bore hole by generating pressure pulses in a drilling fluid in a drill string, the apparatus comprising:
- a vortex valve means, having a vortex chamber which includes radial main inlet ports through which a first portion of said drilling fluid flows, tangential control inlet ports, and an axial outlet, to create a vortex flow in said vortex chamber and thus a high resistance to flow from said inlets to said outlet when fluid is supplied to said control ports and to create substantially radial flow in said vortex chamber and thus a low flow resistance when no fluid is supplied to said control ports; and
- a fluidic feedback oscillator having a power jet supplied by a second portion of said drilling fluid, said oscillator including a first output channel connected to said control inlet ports, a second output channel connected to discharge fluid downstream of said vortex valve, and a means to control the frequency of oscillation of said oscillator in response to signals from said sensors;
- whereby pressure pulses are generated in said drilling fluid in said drill string at a frequency corresponding to the frequency of oscillation of said oscillator and are communicated to the surface.

4,128,812
PHASE DISCRIMINATOR
James D. Pavlis, Gaithersburg, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Aug. 9, 1977, Ser. No. 823,078
Int. Cl.² H03D *13/00*
U.S. Cl. 328—134 **13 Claims**

1. A phase detector for detecting phase synchronism between a first reference input signal and a second input signal comprising:
- a pulse generator which generates pulses at each transition of the first and second input signals, said pulse generator comprising pulse delaying circuits each which receives the input signals, and first gating means which is coupled to receive the input signals and the outputs from the pulse



delaying circuits for producing a high logical output whenever the logical levels of its inputs are not in concert;

means coupled to the pulse generator for producing an output determinative of whether the pulses generated occur concurrently; and

gating means which compare the first and second input signals to the output of the means for determining concurrence for producing an output indicative of phase relationship, whereby the phase relationship is determined.

4,128,836

TIME DELAY COMPUTER FOR ORDNANCE FUSE

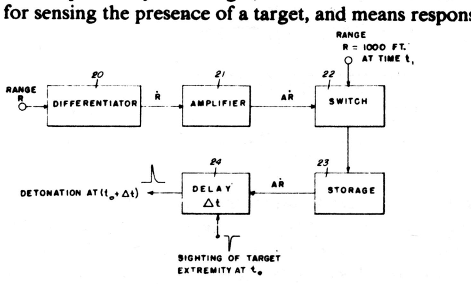
Edward Ramos, and Joseph V. Cuneo, both of Washington, D.C., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.

Filed Oct. 14, 1960, Ser. No. 62,804

Int. Cl.[2] G01S *9/04;* F42C *13/04*

U.S. Cl. 343—7 PF **4 Claims**

1. In a missile having a fuze for detonating the missile warhead in the proximity of a target, means associated with said fuze for sensing the presence of a target, and means responsive



to the sensing of a target by said sensing means for delaying the detonation of said warhead for an internally varied time interval until said missile is at an optimum position with respect to said target.

4,127,788

PIEZOELECTRIC STRESS INDICATOR FOR MINE ROOFS

Ralph N. Daugherty, Rte. 4, Box 54, Front Royal, Va. 22630

Filed Jul. 8, 1977, Ser. No. 814,018

Int. Cl.[2] H01L *41/10*

U.S. Cl. 310—328 **4 Claims**

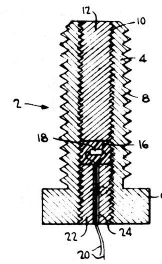
1. A device for detecting deformation in rock strata comprising:

an open cylindrical casing having an inner threaded surface and an outer surface insertable in the strata;

external screw threads on said outer surface to rigidly couple said outer surface to the strata in which said casing is inserted;

a piezoelectric crystal stress sensor;

a block of resinous material in which said sensor is embedded, said block having external threads to rigidly couple



said stress sensor to the inner surface of said casing to transmit deformation of said strata to said stress sensing means and to permit said stress sensor to be coupled to said casing after insertion of said casing in said solid; and

spacer means to axially locate said stress sensor within said casing, said spacer means comprising a solid cylinder threadedly engaged with said inner surface of said casing.

4,126,861

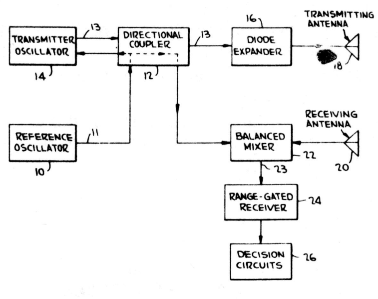
PULSE DOPPLER RANGING SYSTEM (U)

Joseph J. Witte, Silver Spring, Md., and Raymond H. Femenias, Washington, D.C., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.

Filed Mar. 23, 1967, Ser. No. 626,658

Int. Cl.[2] G01S *7/36, 9/14;* H03B *3/08*

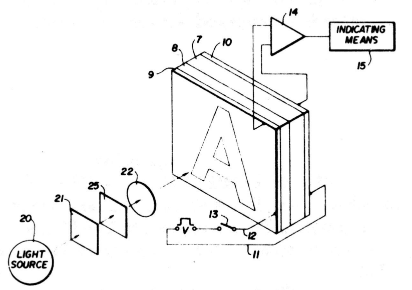
U.S. Cl. 343—13 R **6 Claims**



6. The method of providing the equivalent of a delayed sample of the transmitted signal to the receiver mixer in a pulse radar distance measuring system, comprising the steps of generating a pulse, coupled to and locking the output of a transmitter oscillator in said system, the duration of which corresponds to the time required for a transmitted signal to travel to and return from a target at a predetermined maximum range, and connecting said pulse to said receiver mixer.

4,126,901
PHOTOVOLTAIC-FERROELECTRIC CORRELATION DEVICES
Philip S. Brody, Brookmont, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Continuation-in-part of Ser. No. 824,894, Aug. 15, 1977, Pat. No. 4,051,465, which is a continuation-in-part of Ser. No. 533,365, Dec. 16, 1974, Pat. No. 3,855,004. This application Apr. 5, 1978, Ser. No. 893,568
Int. Cl.² G11C *11/42, 13/04*
U.S. Cl. 365—120 **12 Claims**

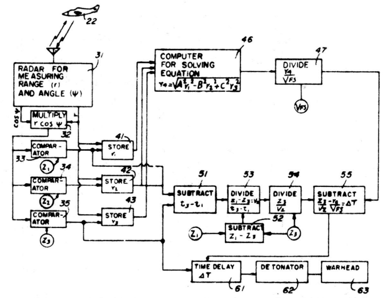
7. A photovoltaic-ferroelectric correlation device for correlating patterns, comprising,
- a layer of photovoltaic-ferroelectric material and a layer of photoconductive material sandwiched between two electrodes, said sandwich having an array of cavities therein,
- means for inducing a remanent polarization pattern in said array of cavities comprising means for applying a voltage across said sandwich and first illumination means for illuminating said cavities with a first illumination pattern while said voltage is applied,



- second illumination means for illuminating said cavities after said voltage is removed with a second pattern to be correlated with said first pattern,
- means for collecting the photocurrent induced in each cavity which photocurrent is proportional to the product of said remanent polarization and the intensity of said second illumination, and
- means for providing an indication of the total current from all of said cavities, which is proportional to the correlation of said two patterns.

4,168,663
COMPUTER FUZES
Hans W. Kohler, Washington, D.C., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Dec. 1, 1954, Ser. No. 472,542
Int. Cl.² F42C *13/04*
U.S. Cl. 102—214 **5 Claims**

1. In an ordnance projectile having a side-spray warhead with a static fragmentation velocity V_{FS}, an ordnance fuze comprising: radar means for making measurements of range



and sight angle of a target; sources of fixed voltages proportional to predetermined target coordinates Z_1, Z_2, and Z_3, in a coordinate system that rides with the fuze, the fuze trajectory being in the plus-Z direction; means for obtaining three voltages proportional to r_1, r_2, and r_3, where r_1, r_2, and r_3 are the fuze-to-target distances when the target Z-coordinates are Z_1, Z_2, and Z_3 respectively; means for obtaining a voltage proportional to V_Z, where V_Z is the rate of change of the Z-coordinate of the target with time; a source of fixed voltage proportional to said static fragmentation velocity V_{FS}; electronic computer means for solving the equation

$$\Delta T = Z_3/V_Z - r_4/V_{FS},$$

where

$$r_4 = \sqrt{A^2 r_1{}^2 - B^2 r_2{}^2 + C^2 r_3{}^2},$$

$$A^2 = \frac{Z_2\,Z_3}{(Z_1 - Z_3)\,(Z_1 - Z_2)},$$

$$B^2 = \frac{Z_1\,Z_3}{(Z_1 - Z_2)\,(Z_2 - Z_3)},$$

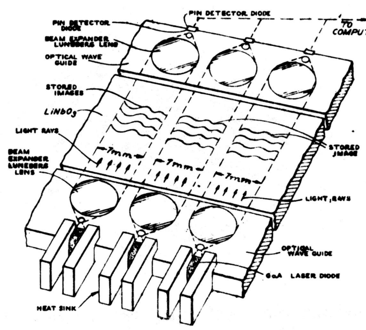
and

$$C^2 = \frac{Z_1\,Z_2}{(Z_1 - Z_3)\,(Z_2 - Z_3)},$$

r_4 being the fuze-to-target distance corresponding to Z = zero, said computer means including a subcomputer for solving the equation $r_4 = \sqrt{A^2 r_1{}^2 - B^2 r_2{}^2 + C^2 r_3{}^2}$; and means for causing detonation of said warhead at time $t_3 + \Delta T$, where t_3 is the time at which the Z-coordinate and distance of the target are Z_3 and r_3 respectively.

4,124,281
SCHEME FOR TERMINAL GUIDANCE UTILIZING ACOUSTO-OPTIC CORRELATOR
Norman J. Berg, Baltimore, and Burton J. Udelson, Bethesda, both of Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jun. 7, 1977, Ser. No. 804,204
Int. Cl.² G02F *1/32*
U.S. Cl. 350—358 **5 Claims**

1. An acousto-optic correlation device for use in a terminal guidance system for guiding a vehicle to a target area, comprising
- an elongated acousto-optic crystal having a plurality of storage positions along its length, each storage position corresponding to a one dimensional strip of said target area, each storage area having a signal stored therein as an index of refraction variation pattern, each stored signal corresponding to the variation of a characteristic parameter such as reflectivity of the target area strip which corresponds to the storage position,

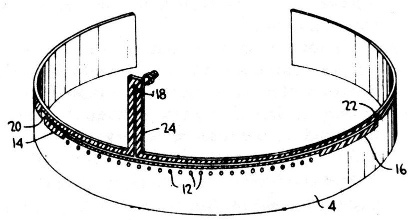


means for sequentially propagating real time acoustic signals across all of said stored signals, said real time signals corresponding to the variation of said characteristic parameter of one dimensional strips of the scene actually being viewed by said vehicle,

laser means irradiating said storage positions, and,

a photodetector means associated with each storage position and located so that the laser light from said laser means is incident thereon after traversing said storage positions.

4,110,751
VERY THIN (WRAP-AROUND) CONFORMAL ANTENNA
Frank Reggia, Bethesda, Md., and Howard S. Jones, Jr., Washington, D.C., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Mar. 10, 1977, Ser. No. 776,161
Int. Cl.^{2} H01Q *13/18, 1/38*
U.S. Cl. 343—700 MS **12 Claims**



1. A thin wrap-around, conformal antenna comprising:

a conformal dielectric substrate;

conductive plating on the interior surface of the substrate;

conductive plating on the exterior surface of the substrate the plating defining a cavity region for a pair of radiating elements;

shorting means for forming the boundaries of the cavity-backed radiating elements placed along the periphery of the elements except for a single cavity radiating region on each element; and

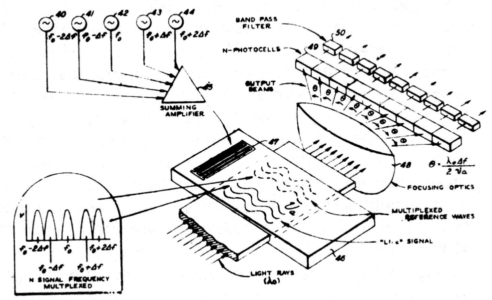
a stripline feed network for nonsymmetrically coupling energy to the individual radiating elements at selected points along the radiating region whereby microwave energy may be received or transmitted.

4,124,280
ACOUSTIC-OPTIC TECHNIQUE FOR PROCESSING MANY SIGNALS SIMULTANEOUSLY
Norman J. Berg, Baltimore, Md., and James T. Karam, Jr., Reston, Va., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Jun. 7, 1977, Ser. No. 804,202
Int. Cl.^{2} G02F *1/32*
U.S. Cl. 350—355 **3 Claims**

1. An acousto-optic apparatus for processing first and second sets of composite signals and for obtaining the correlation of the envelope for each composite signal in said first set with the envelope of a respective composite signal in said second set, comprising,

a piezoelectric crystal having said second set of composite signals stored therein as respective overlapping index of refraction variation patterns over a given surface area of said crystal, each of said stored composite signals being comprised of an R.F. signal modulated by an envelope, with the R.F. frequency of each composite signal in said second set being different from the R.F. frequency of each other signal in said set, said crystal having acoustic transducer means disposed thereon to one side of said given surface area for converting electrical signals which are applied thereto to corresponding acoustic signals,

said first set of composite signals comprising a set of electrical signals, each of said electrical signals being comprised



of an R.F. signal modulated by an envelope, with the R.F. frequency of each composite signal in said first set being different from the R.F. frequency of each other signal in said set of said first set being the same as the R.F. frequency of one signal of said second set of signals,

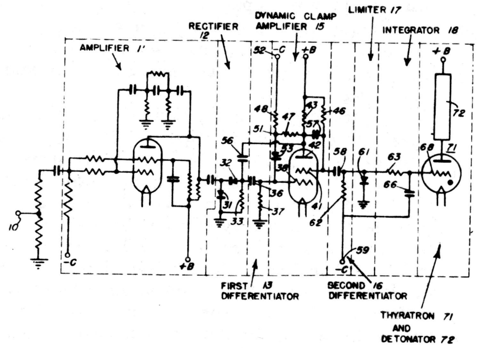
means for applying said first set of composite signals to said acoustic transducer means,

laser means directed to transmit a laser beam across said given surface area and

detector means for detecting said laser beam after it traverses said surface portion.

4,122,776
DYNAMIC CLAMP CIRCUITS
Paul M. Tedder, Gainesville, Fla., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Sep. 3, 1954, Ser. No. 454,237
Int. Cl.^{2} F42B *5/08, 9/08, 21/38*
U.S. Cl. 102—214 **2 Claims**

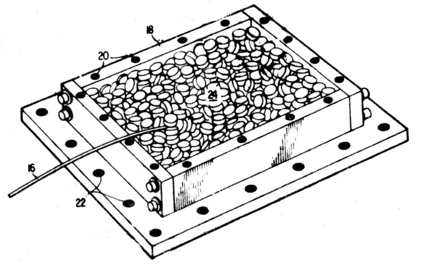
1. An electronic ordnance fuze adapted to function upon receiving a target signal that increases in amplitude for at least a predetermined length of time, said fuze comprising: input means adapted to receive an alternating-current signal of increasing amplitude; first means for obtaining from said alternating-current signal a first negative-going unipotential signal of increasing amplitude, a ripple frequency due to the original alternating current being superimposed on said unipotential signal; an amplifier tube having at least a control grid, a screen grid, and an anode; means for applying said negative-going unipotential signal to said control grid; sources of direct current supply voltage for said screen grid and said anode, the voltage at the screen grid being maintained more positive than the voltage at the anode and the operating conditions being so



maintained that the anode current remains substantially saturated for control grid signals more positive than a predetermined negative value; means for taking an amplified unipotential signal from said screen grid, said screen grid thus resembling functionally the plate of a triode amplifier; first and second capacitor means for coupling said ripple frequency present in said first negative-going unipotential signal to said screen grid and to said anode, said capacitor means tending to filter out said ripple, the degree of filtering being dependent upon the gain of said amplifier tube; means for obtaining a direct-current feedback voltage from said anode; a biased diode; means for applying said feedback voltage to said control grid through said biased diode, so that, if said alternating-current signal is of sufficient amplitude and increases in amplitude at an abnormally large rate, a direct-coupled inverse feedback voltage is applied to said control grid, reducing the gain of said amplifier but permitting the ripple-frequency output of said amplifier to increase; resistance-capacitance differentiator means adapted to produce a unipotential output signal upon receiving a positive-going unipotential signal from said screen grid of said amplifier; diode rectifier-limiter means connected between the output of said differentiator means and ground, said rectifier-limiter means serving to prevent the output of said differentiator means from rising appreciably above ground potential and serving also to rectify any component of said ripple frequency present in the input of said differentiator means, so as to make the output of said differentiator means more negative when the ripple-frequency output of said amplifier increases; resistance-capacitance integrator means connected to the output of said differentiator means; a thyratron; means for applying to the grid of said thyratron a signal from the output of said integrator means; and fixed bias means for maintaining the output of said differentiator and the grid of said thyratron a values sufficiently negative to prevent firing of said thyratron in the absence of a signal.

4,118,861
REMOVABLE ENCAPSULANT FOR PROTECTION OF ELECTRONIC EQUIPMENT
Rocco Richard Palmisano, Bethesda, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Feb. 6, 1976, Ser. No. 656,050
Int. Cl.² H01B *19/00*
U.S. Cl. 29—631 **3 Claims**

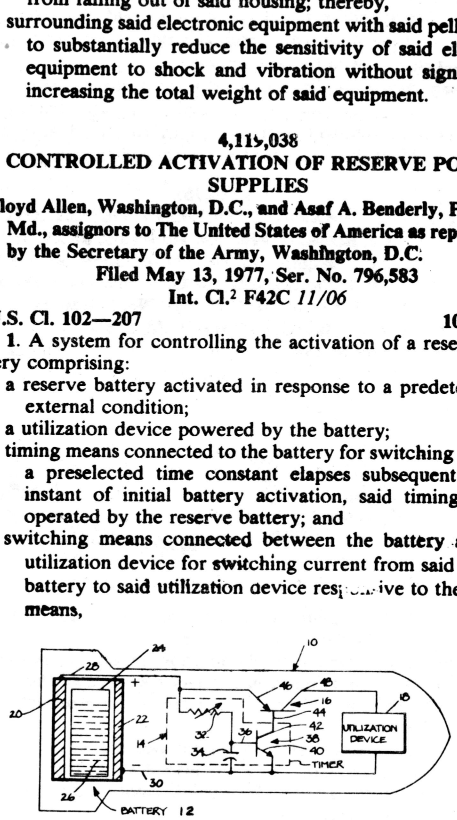
1. A new use for silicone rubber, formed from the reaction of a prepolymer comprising a silane and silanol in the presence of a catalyst, as a removable encapsulent for electronic equipment comprising the steps of:
dividing a body formed of said silicone rubber into pellets;
pouring said pellets of silicone rubber material into a housing



containing electrical equipment so as to fill the voids between said housing and said electrical equipment; and,
enclosing said housing to prevent said silicone rubber pellets from falling out of said housing; thereby,
surrounding said electronic equipment with said pellets so as to substantially reduce the sensitivity of said electronic equipment to shock and vibration without significantly increasing the total weight of said equipment.

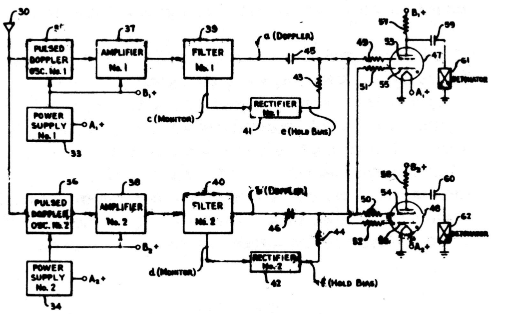
4,119,038
CONTROLLED ACTIVATION OF RESERVE POWER SUPPLIES
Floyd Allen, Washington, D.C., and Asaf A. Benderly, Potomac, Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed May 13, 1977, Ser. No. 796,583
Int. Cl.² F42C *11/06*
U.S. Cl. 102—207 **10 Claims**

1. A system for controlling the activation of a reserve battery comprising:
a reserve battery activated in response to a predetermined external condition;
a utilization device powered by the battery;
timing means connected to the battery for switching on after a preselected time constant elapses subsequent to the instant of initial battery activation, said timing means operated by the reserve battery; and
switching means connected between the battery and the utilization device for switching current from said reserve battery to said utilization device responsive to the timing means,



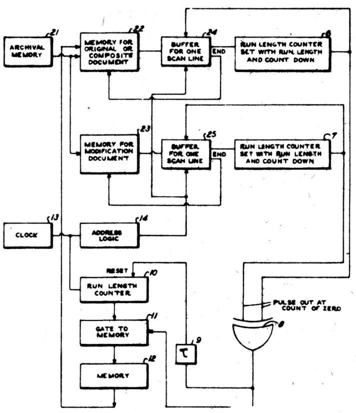
said timing means operating said switching means upon lapsing of said preselected time constant, so that the utilization device draws load current from the battery only after full activation of the battery thereby preventing polarization of the battery.

4,119,039
FUZE SYSTEM
Paul E. Wilkins, Fairfax, Va.; Glenn E. Neville, Washington, D.C., and Robert T. Fitzgerald, Rockville, Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed May 29, 1961, Ser. No. 113,991
Int. Cl.² F42C *13/04*
U.S. Cl. 102—214 **4 Claims**



1. A fuze system comprising in combination: an antenna, a plurality of independent channels, a firing circuit, and detonator means; each of said channels comprising oscillating detector means for generating a transmitting signal and a monitoring signal, said detector means upon receipt of a target signal having an output containing a doppler frequency component, amplifying means connected to said oscillating detector means, means connected to said amplifying means for separating said monitoring signal from said doppler target signal, and rectifying means for forming a d-c holding bias from said monitoring signal; said firing circuit having first and second inputs; means for applying both the holding bias and the doppler target signal of one of said channels to said first firing circuit input, and means for applying both the holding bias and the doppler target signal of another one of said channels to said second firing circuit input said means responsive to said monitoring means enabling said fuze to operate by any remaining channels upon failure of one channel; said detonator means being connected to the output of said firing circuit.

4,121,196
DATA BASE UPDATE SCHEME
Richard N. Johnson, and Marvin J. Schneider, both of Adelphi, Md., assignors to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed May 2, 1977, Ser. No. 792,832
Int. Cl.[2] G02B ***5/00;*** **G03B** ***21/14;*** **G06K** ***9/00***
U.S. Cl. 340—146.3 P **4 Claims**



1. An apparatus for modifying the contents of a storage memory which stores original picture information which is encoded in the memory in accordance with the run length encoding compaction algorithm, said picture information being delineated by picture line in said memory, for each picture line said stored information comprising a group of numbers which locate the relative positions of picture elements along the line, comprising,

a modification memory having picture modification information stored therein in accordance with the run length encoding compaction algorithm, said modification information being delineated by picture lines in said memory which correspond to said picture lines in said storage memory, said modification information for each line comprising a group of numbers which locate the relative positions along that line at which picture elements are to be either added or deleted to said original picture information,

means for extracting the information from the respective memories on a line by line basis,

means responsive to said information extracted for modifying the group of numbers stored in said storage memory for each line by 1) adding numbers which are indicative of positions along that line at which the numbers in said storage memory do not locate a picture element but the numbers in said modification means do locate a picture element, and, 2) deleting numbers which are indicative of positions at which both the numbers in said storage memory and the numbers in said modification memory locate picture elements.

4,126,394
OPTICAL CANT SENSOR FOR MORTARS
Reinhard R. Ulrich, Rockville, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Aug. 9, 1977, Ser. No. 823,079
Int. Cl.[2] G01B ***11/26;*** **F41G** ***3/16***
U.S. Cl. 356—152 **5 Claims**

1. An optical cant sensor for mortars comprising:

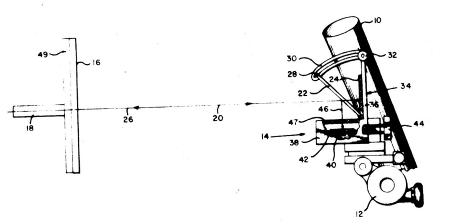
a source of light;

a first mirror vertically mounted to the barrel of the mortar for reflecting light from the light source;

a viewing screen upon which the reflected light impinges;

a second mirror mounted to the barrel for maintaining a reflecting plane level with the ground;

a semi-reflective mirror positioned between the first and second mirrors for diverting light from the source to the second mirror, the semi-reflective mirror directing light reflected from the second mirror to the viewing screen,



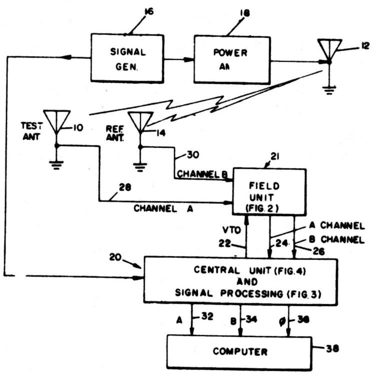
and for permitting light passsage between the source and viewing screen via the first mirror; and

means for adjusting the semi-reflective mirror to superimpose images from the first and second mirrors;

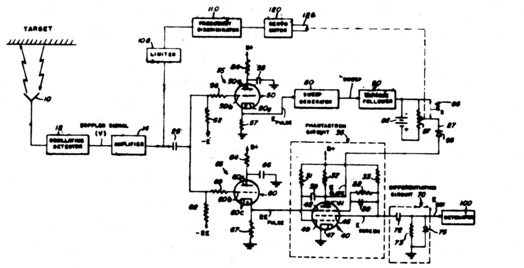
whereby repeated mortar firings produce cant which is manifest by displacement of the superimposed images.

4,118,668
R.F. NETWORK ANTENNA ANALYZER EMPLOYING SAMPLING TECHNIQUES AND HAVING REMOTELY LOCATED SAMPLING PROBES
Roy E. Strayer, Jr., Manassas Park, Va., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Sep. 12, 1977, Ser. No. 832,494
Int. Cl.² H04B *17/00*
U.S. Cl. 325—67 **10 Claims**

1. A dual channel network analyzer for testing an antenna in comparison with a reference antenna, the analyzer comprising:
first sampling means associated with each channel for respectively sampling, at a preselected rate, either first or second r.f. signals from the tested antenna and reference antenna resulting in the conversion of said signals to intermediate frequency;
signal generating means having a first output connected in circuit with a transmission antenna which transmits signals to the tested antenna and reference antenna simultaneously;
second sampling means for sampling, at the preselected rate, a second output of the signal generating means;
phase lock loop means having an input connected to the output of the second sampling means;
voltage tuned oscillating means connected to the output of the phase lock loop means for generating a signal which establishes the preselected rate;
phase metering means having inputs respectively connected to the first and second converted signals for producing a phase measurement of the first signal relative to the second;
first analog-digital conventing means for converting the phase measurement to a digital signal;
second and third analog-digital converting means for converting the first and second signals to digital signals representing the respective amplitudes of the signals derived from the test and reference antennas; and
means respectively connected to the outputs of the analog-digital converting means for allowing connection of the digital phase and amplitude signals to a computer.



4,118,702
DOPPLER DISTANCE MEASURING SYSTEM
Jacob Rabinow, Takoma Park, Md., assignor to The United States of America as represented by the Secretary of the Army, Washington, D.C.
Filed Apr. 22, 1959, Ser. No. 808,277
Int. Cl.² G01S *7/42, 9/46*
U.S. Cl. 343—7 PF **5 Claims**



1. A system for mesuring the distance to a target comprising: means for transmitting a signal to said target and for receiving a return signal from said target, means for mixing said transmitted signal and said return signal to produce a doppler signal, means connected to said mixing means and responsive to said doppler signal for initiating a first voltage timing function, means having a signal input connected to said mixing means and responsive to said doppler signal and a gating input responsive to said first timing function for initiating a second voltage timing function when said dopper signal reaches a predetermined value, and means connected to said means for initiating a second voltage timing function and responsive to said second timing function for producing a signal when said target is at a predetermined distance from said transmitting and receiving means.

patent applications

Application title	Serial No.	Filing date	Inventor(s)
Submillimeter Wave Generation Using Surface Acoustic Waves in Peizoelectric Materials	952,921	18 Oct 1978	Nick Karayianis Donald E. Wortman
Null Balancing for Fluidic Sensors and Amplifiers	953,292	20 Oct 1978	Francis M. Manion Charles E. Paras
Improved Phase Measuring Device	957,779	6 Nov 1978	James S. Shreve
Non-Contact Flueric Temperature Sensing Method and Apparatus	963,720	27 Nov 1978	Tadeusz M. Drzewiecki
Flueric Notch Filter Temperature or Density Sensor	963,719	27 Nov 1978	Francis M. Manion Tadeusz M. Drzewiecki Richard M. Phillippi Charles E. Paras
Conformal Spiral Antenna	966,839	6 Dec 1978	Arthur R. Sindoris Frederick G. Farrar Daniel H. Schaubert
Coaxial Terminal Protection Device with Disposable Cartridge	003,179	15 Jan 1979	Rudolph J. Prochazka
A Method and Apparatus for Determining Aerosol Size Distributors	004,979	22 Jan 1979	Clyde A. Morrison Nick Karayianis Donald E. Wortman
Wideband Self-Calibrated Fiber-Optic Data Link with Fiber-Optic Storage	006,829	26 Jan 1979	Raine M. Gilbert

Application title	Serial No.	Filing date	Inventor(s)
Binary Integrator for Fixed Cell Radar Alarm Data	008,808	2 Feb 1979	David J. Buscher Marvin J. Schneider
Fluidic Valve	008,627	1 Feb 1979	George Mon
ROACH Generator	008,628	1 Feb 1979	James S. Shreve
Temperature-Compensated Laminar Proportional Amplifier	014,503	23 Feb 1979	George Mon
Solid-Medium Coherent Optical Processor	019,031	9 Mar 1979	James S. Shreve
Complex Spatial Modulator	019,032	9 Mar 1979	James S. Shreve
Multislot Bicone Antenna	024,234	26 Mar 1979	Dieter R. Lohrmann
Array Antenna Controller	029,421	12 Apr 1979	James S. Shreve
Output Coupling System for Near-Millimeter Microwave Source	042,681	25 May 1979	Colin S. Willett
Multi-Beam Antenna Controller	042,688	25 May 1979	James S. Shreve
Improved Null Mask	047,676	12 Jun 1979	James S. Shreve
Optical Memory with Fiber Optic Light Guide	047,675	12 Jun 1979	Philip S. Brody
Multilayer Store Beam Accessed Memory	050,365	20 Jun 1979	Philip S. Brody
Automated Exposure-Contrast Control Index Meter	052,300	26 Jun 1979	James S. Shreve
Non-Slip Turning Joint for Fuzes	057,873	16 Jul 1979	David L. Overman
Efficient High Voltage Photovoltaic Cells	060,525	25 Jul 1979	Philip S. Brody
Nuclear Energy Device Using Very High Particle Density and Electrical Initiation	065,395	24 Jul 1979	William W. Carter
Fluid Oscillator	064,451	7 Aug 1979	Allen B. Holmes
Adjustable Parallel Fluidic Resistor Bank	070,772	30 Aug 1979	John F. Burke

Application title	Serial No.	Filing date	Inventor(s)
Method and Apparatus for Reduction of Modal Noise in Fiber Optic Systems	—	12 Sept 1979	James C. Blackburn Jonathan Vanderwall
Fluidic Mud Pulser	074,636	12 Sept 1979	Allen B. Holmes Stacy E. Gehman Maurice F. Funke
Gun Tube Orientation Sensor; Target Mirror	077,441	20 Sept 1979	Morton A. Barron
Apparatus and Method for Temperature Compensation of Fluidic Circuits	077,442	20 Sept 1979	Tadeusz M. Drzewiecki
Fluidic Pulser	—	Sept 1979	Allen B. Holmes

awards and recognition

Hinman Award for Technical Leadership

Robert N. Johnson

The Hinman Award for Technical Leadership is awarded to Robert N. Johnson in recognition of his outstanding technical leadership in guiding an in-house team and contractors through the final stages of development, DT/OT-II testing, and type classification of the Army's first electronic time fuze for artillery. Major factors in the successful completion of the M724/587 fuze development included his personal technical contributions to the design; his relationships with sponsors, TECOM and TRADOC; and his tireless assistance to others in the review of design, technical data package, and hardware scheduling.

Hinman Award for Technical Achievement

James M. McGarrity and Harold E. Boesch, Jr.

The Hinman Award for Technical Achievement is awarded to James M. McGarrity and Harold E. Boesch for the conceptualization and development of an electrical technique to measure the radiation susceptibility of MOS gate insulators. The importance of this technique is that, for the first time, the nuclear effects community will have a tool for sampling or screening for the total dose hardness of gate oxides produced on a wafer process line. This purely electrical technique (called field-induced injection and impact ionization) is a breakthrough in radiation hardness testing and quality assurance.

Ulrich Award for Managerial Leadership

Kathleen T. Hering

The Ulrich Award for Managerial Leadership is awarded to Kathleen T. Hering for her inspiring leadership in management-employee relations and union negotiations. Through her personal efforts, she provided the management and employees of HDL and tenant activities with analysis, insight, and recommendations necessary to resolve management/employee problems; as the principal team leader and advisor, she developed and/or caused to be developed management's positions on specific union contract proposals during ongoing negotiations.

Ulrich Award for Managerial Achievement

Mary Brooke Minor

The Ulrich Award for Managerial Achievement is awarded to Mary Brooke Minor in recognition of her outstanding performance and many contributions which, while enhancing the ability of the Laboratory to meet its goals, have also significantly enlarged the present concept of the Labora-

tory Administrative Officer's role at the Harry Diamond Laboratories.

HDL Inventor of the Year Award

Norman J. Berg

Norman J. Berg is hereby cited for his innovative contributions in the field of acousto-optic signal processing. The advances in technology and the devices that have resulted from his ingenuity have placed HDL in the international forefront of scientific activity in this field.

Other Awards. During FY79, performance awards granted included 3 Honorary Awards, 14 Outstanding Performance Ratings, 27 Sustained Superior Performance Awards, 39 Special Act Awards, and 17 Quality Step Increases. In addition to the performance awards, there were 29 Initial Patents, 26 Allowable Patents, and 27 adopted suggestions (for the usual reporting purposes Patents are credited as suggestions). Tangible benefits resulting from the adopted suggestions amounted to approximately $17,113.32.

Special Achievement Awards. Alfred J. Kinkead was granted a monetary award of $100 in recognition of his value engineering proposal which resulted in a net savings of $5760 over a three-year period. Mr. Kinkead designed a new metal test fixture for testing turbine alternators for the M734 program. The design not only resulted in a sizable dollar savings, but also established standardized test techniques which give uniform and reliable results.

Student Technical Symposium. Winners of HDL's 20th Annual Summer Student Technical Symposium included Thomas W. Daley, First Place Winner, for preparation and presentation of his paper, *Optically Pumped Freon-22 Near Millimeter Laser*; Gary H. Stolovy, Second Place Winner, for his paper, *Computer Study of a Target/Cloud Discrimination Scheme for a Fanbeam Optical Fuze*; David A. Hahn, Third Place Winner, for his paper, *An Investigation into Aerial Protection in the Event of a Mortar Hangfire at Blossom Point*; and Stewart M. Gutoff, Fourth Place Winner, for his paper, *Computer Modeling of a Vibration Test Fixture.*

Significant Adopted Suggestion Based on First Year Savings. Seth B. Butler proposed modifications in the plating shop to reduce waste treatment. His suggestion was adopted and resulted in cost savings in labor and material of approximately $9573. Additionally, adoption of the suggestion improved the health and safety situation in the waste treatment plant. Since his first-year savings exceeded $5000, Mr. Butler will be nominated for Presidential recognition.

Acronyms and Abbreviations

AAH	Army Attack Helicopter
ABRES	Advanced Ballistic Reentry Systems
AD	air defense
ADP	automated data processing
ADVT-C	advanced development and verification tests—contractor
ADVT-G	advanced development and verification tests—government
AESOP	Army EMP Simulator Operation
AFB	Air Force Base
AFRRI	Armed Forces Radiobiology Research Facility
AGE	aerospace ground equipment
AHAMS	Advanced Heavy Anti-armor Missile System
AIF	Army Industrial Fund
ALM	antenna leakage modulation
AM	amplitude modulation
AMETA	US Army Management Engineering and Training Agency
AMMRC	Army Materials and Mechanics Research Center
AMP	AURORA Modification Project
AMSAA	US Army Materiel Systems Analysis Activity
AOF	active optical fuze
APACHE	Assessment of Pacific Communications for Hardening to EMP
APG	Aberdeen Proving Ground
APRF	Army Pulse Radiation Facility
ARBS	Angular Rate Bombing System
ARM	anti-radiation missile
ARO	Army Research Office
ARP	anti-radiation projectile
ARRADCOM	Armament Research and Development Command
ARRCOM	Armament Materiel Readiness Command
ARTEP	Army Training and Evaluation Program
ASARC	Army System Acquisition Review Council
ASA(RDA)	Assistant Secretary of the Army (Research, Development, and Acquisition)
ASC	Advanced Simulation Center
ASD	arming safety device
ASL	Atmospheric Sciences Laboratory
ASM	air-to-surface missile
ATAGS	Army Tactical Communication System
ATRF	Advanced Technology Radar Fuze
ATSM	American Society for Testing and Materials
ATSS	Automotive Test Support Systems
AUTOVON	Automatic Voice Network
AVE	aerospace vehicle equipment
AVRADCOM	Aviation Research and Development Command
BAFI	Base Antenna Flight Instrumentation
BETA	Battlefield Exploitation and Target Acquisition
BISSPO	Base Installation Security Systems Project Office
BITE	Built-In Test Equipment
BLIP	Beam Leaded Interconnect Package
BP	Blossom Point
BRL	Ballistic Research Laboratory
C^2	command and control
C^3	command, control, and communications
C^3/D	command, control, and communications degradation
C^4	command, control, communications, and computers
CACDA	Combined Arms Center, Combat Development Activity
CAD	computer-aided design
CAM	computer-aided manufacture
CAS	Chief, Army Studies
CAWS	Cannon Artillery Weapon System
CCC	Command and Control Center
CCM	counter-countermeasures
CDEC	Combat Development Experimentation Command
CEEIA	Communication Electronic Engineering Installation Agency
CEP	circular error probable
CERCOM	Communications and Electronics Materiel Readiness Command
CEWI	Combat Electronic Warfare Intelligence
CFAR	constant false alarm rate
CINCPAC	Commander-in-Chief, Pacific
CLGP	Cannon Launched Guided Projectile
CM	countermeasures
CMOS	complementary metal oxide semiconductor
CMT	computerized modal testing
CNWDI	Critical Nuclear Weapon Design Information
C/N	carrier to noise ratio
COMSEC	communications security
CONUS	continental United States

Acronyms and Abbreviations (cont'd)

CORADCOM	Communications Research and Development Command
CRIC	Component Research Information Center
CRT	cathode ray tube
CSD	cross-spectral density
CSG	coaxial spark gap
CSTAL	Combat Surveillance Target Acquisition Laboratories
CVC	coaxial voltage clamp
cw	continuous wave
DARCOM	US Army Materiel Development and Readiness Command
DCA	Defense Communications Agency
DCAS	Defense Contracts Administrative Service
DCEC	Defense Communications Engineering Center
DCS	Defense Communication System
DCSOPS	Deputy Chief of Staff for Operations
DCSRDA	Deputy Chief of Staff for Research, Development, and Acquisition
DCTS	Digital Control Test System
DDR&E	Directorate for Defense Research and Engineering
DEA	Data Exchange Agreement
DEB	Digital European Backbone
DEVA-IPR	Development Acceptance—In Process Review
DFT	discrete Fourier transform
DIVADS	Division Air-Defense System
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DORF	Diamond Ordnance Radiation Facility
DR	Design Review
DSCS	Defense Satellite Communications System
DSMC	Defense Systems Management College
DSVT	digital subscriber voice terminal
DT	developmental test
DT/OT	developmental testing/operational testing
EAD	echelons above division
EBM	explosive barrier module
ECCM	electronic counter-countermeasures
ECIP	Energy Conservation Investment Program
ECP	Engineering Change Proposal
ECM	electronic countermeasures
ECOM	Electronics Command
EDA	Economic Development Administration
EDT	engineering development tests
EED	electro-explosive detonator
EEO	Equal Employment Opportunity
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELINT	electronic intelligence
EMCON	emission control
EMP	electromagnetic pulse
EO	electro-optic
EPA	Environmental Protection Agency
EPP	electric power plant
ERADCOM	Electronics Research and Development Command
ERDA	Energy Research and Development Agency
ERGP	extended-range guided projectile
ESF	Electromagnetic Simulation Facility
ESG	Environmental Simulation Group
ESS	Electronic Switching System
EUCOM	European Command
EW	electronic warfare
EWL	Electronic Warfare Laboratory
F/A	frequency to analog
FASCAM	family of scatterable mines
FCS	fire control system
FDN	Future Data Network
FET	field-effect transistor
FFS	fuze function setter
FFT	fast Fourier transform
FHRU	fluidic heading reference unit
FIR	finite impulse response
FKV	Frankfurt-Koenigstuhl-Vaihingen (network)
FLC	Federal Laboratory Consortium for Technology Transfer
FM	frequency modulation
FMEA	failure mode and effect analysis
FOJ	fuze-on-jam
FSED	full-scale engineering development
FSTC	Foreign Science and Technology Center
FTG	Field Test Group
FUSE	Fighting Unit Survivability Evaluation
FVS	Fighting Vehicle System
GEMSS	ground emplaced mine scattering systems
GFE	government-furnished equipment

Acronyms and Abbreviations (cont'd)

GIFTS	finite element mechanical analysis program
GLD	Ground Laser Designator
GLLD	Ground Located Laser Designator
GO-CO	government-owned, company-operated
GO-GO	government-owned, government-operated
GPSS	general-purpose simulation system
GSRS	General Support Rocket System
HAEMP	high-altitude electromagnetic pulse
HATS	Hardened Tactical Shelter
HBA	hardened base antenna
HCC	hybrid coaxial clamp
HDL	Harry Diamond Laboratories
HE	high explosive
HEAT	high explosive antitank
HELBAT	high-energy laser test
HELSPO	High-Energy Laser Systems Project Office
HEP	high-explosive plastic
HEPC	Hispanic Employment Program Coordinator
HERO	hazards of electromagnetic radiation to ordnance
HIFX	High-Intensity Flash X-Ray
HOB	height of burst
HSM	hard-structure munition
HT	heavy terminal
IC	integrated circuit
IDEAS	Interactive Data Evaluation Analysis System
IEMP	internal electromagnetic pulse
IF	intermediate frequency
IHAWK	Improved Hawk
IIR	imaging infrared
IJO	Individual Job Order
ILIR	In-House Laboratory Independent Research
IMDSO	Intelligence Materiel Development and Support Office
IMPATT	impact avalanche transit time
INCA	Integrated Nuclear Communications Assessment
INSCOM	Intelligence and Security Command
INTACS	Integrated Tactical Communications System
INTRAD	Integrated Transitional Hardware
IPF	Initial Production Facility
IR&D	Independent Research and Development
IR	infrared
IRS	inductive remote set
ISC	International Signal and Control Corp.
ISO	International Standards Organization
ISR	Installation Security Radar
ISTA	intelligence, surveillance, and target acquisition
ITD	Information Technology Development
ITV	Improved TOW Vehicle
IVD	ion-vapor-deposited (aluminum)
JLC	Joint Logistics Commanders
JPL	Jet Propulsion Laboratory
JTCG-Fluidics	Joint Technical Coordinating Group on Fluidics
JWG	Joint Working Group
LATHES	Laser Terminal Homing Engagement Simulator
LAW	light antitank weapon
LC	inductor-capacitor
LD	laser designator
LED	light-emitting diode
LINAC	linear accelerator
LJARS	laminar jet angular rate sensor
LPA	laminar proportional amplifier
LSI	large-scale integration
LSIC	large-scale integrated circuit
LWCMS	Lightweight Company Mortar System
MACI	Military Application of Commercial Items
MCA	military construction, Army
MCC	multifunction coaxial clamp
MCF	mutual coherence function
MERADCOM	Mobility Equipment Research and Development Command
MHAT	mechanical high-altitude timer
MIC	microwave integrated circuit
MICOM	Missile Command (formerly MIRADCOM)
MICV	Mechanical Infantry Combat Vehicle
MIL DEP	Military Department
MIL-STD	Military Standard
MINIRAD	Miniature Radar Fuze
MIRADCOM	Missile Research and Development Command (now MICOM)
MIS	metal insulator semiconductor
MISO	Management Information Systems Office
MLE	Microelectronics Laboratory Facility
MMF	mobile measurement facility
MM&T	manufacturing methods and technology
MNOS	metal nitride oxide semiconductor
MOF	multi-option fuze

MOS	metal-oxide semiconductor
MOTS	metal-oxide threshold switch
MOUT	Military Operations in Urban Terrain
MRA	Malibu Research Associates
MRC	Mission Research Corp.
MSE	mean square error
MSEP	Multiple Systems Evaluation Program
MSO	Maintenance Service Orders
MTBF	mean time between failure
MTI	moving target indicator
MTT	materials test technology
NAIF	Non-Army Industrial Fund
NARADCOM	Natick Research and Development Command
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVCAMS EASTPAC	Naval Communications Area Master Station, Eastern Pacific
NBC	nuclear fallout, biological, and chemical effects
NCA	National Command Authority
NEP	noise-equivalent power
NEST	Nuclear Effects Support Team
NMCS	National Military Command System
NMMW	near-millimeter wave
NRL	Naval Research Laboratory
NSA	National Security Agency
NSF	National Science Foundation
NSWC-DL	Naval Surface Weapons Center, Dahlgren Laboratories
NSEC-WOL	Naval Surface Weapons Center, White Oak Laboratories
NTIS	National Technical Information Service
NUDACC	nuclear damage assessment code
NVEOL	Night Vision and Electro-Optics Laboratory
NWC	Naval Weapons Center
NWE	nuclear weapons effects
NWER/T	Nuclear Weapons Effects Research and Testing
OMEW	Office of Missile Electronic Warfare
ONR	Office of Naval Research
OPR	outstanding performance rating
OPSEC	operations security
OSHA	Occupational Safety and Health Administration
OT	operational testing
OTEA	Operational Test and Evaluation Agency
OUSDR&E	Office of the Undersecretary of Defense, Research and Engineering
OWL	oil-water line
PACOM	Pacific Command
PAG	Programming Assistance Group
PAL	permissive action link
PBP	protective binding post
PBS	production base support
PD	point detonating
PEP	Production Engineering Planning
PIF	Provision of Industrial Facilities
PIP	Product Improvement Program
PM	phase modulation *or* Project/Program/Product Manager
PMCAC	Program Manager, Command and Control
PMO	Project/Program/Product Manager's Office
PMP	paralleled microprogrammed processor
PMSA	Project Manager for Selected Ammunition
POPS	Parachute-Opening Proximity Sensor
PQM	Product Quality Manager
PREMPT	Program for Electromagnetic Pulse Test
QA	quality assurance
QSI	quality step increase
QSTAG	Quadripartite Standardization Agreement
RAAM	Remote Anti-Armor Mine
RAM	reliability, availability, and maintainability *or* random access memory
RAT SCAT	Radar Target Scatter
RC	resistor capacitor
RCS	radar cross section
R&D	research and development
RDTE	research, development, test, and evaluation
REPS	Repetitive Electromagnetic Pulse Simulator
RES	Reflected Energy Simulator
rf	radio frequency
RFP	Request for Proposals
RFSS	Radio Frequency Simulation System
ROM	read-only memory
RPG	Repetitive Pulse Generator
RPV	remotely piloted vehicle
RS	remote set
R&QA	reliability and quality assurance
S2K	System 2000
SA	Selected Ammunition

Acronyms and Abbreviations (cont'd)

S&A	safety and arming
SAFCA	Safeguard Communications Agency
SALGP	semi-active laser-guided projectile
SAM-D	Surface-to-Air Missile, Development (now Patriot)
SAMSO	Space and Missile Systems Organization (US Air Force)
SASP	special ammunition supply points
SAW	surface acoustic wave
SCCS	Simulation Central Coordinating Subcommittee
SCR	silicon-controlled rectifier
SCU	setter control unit
SDR	System Design Review
SEM	scanning electron microscope
SGEMP	system-generated electromagnetic pulse
SINCGARS-V	Single-Channel Ground and Airborne Radio System—VHF
SHAWL	Special Hard Target Assault Weapon, LAW
SMAW	shoulder-launched multipurpose assault weapon
S/N	signal-to-noise ratio
SOO	Standard Operating Orders
SOP	Standard Operating Procedure
SOTAS	Standoff Target-Acquisition System
SOW	Statement of Work
SPEF	single program element funded
SPF	single project funded *or* surface proximity fuze
SPICE 2	large circuit (electronics) simulator program
SPLL	self-propelled launcher loader
SRWBR	Short-Range Wideband Radio
SSEB	Source Selection Evaluation Board
SSJ	self-screening jammer
SSP	sustained superior performance
SRR	Systems Requirement Review
SSS	shock spectrum synthesis
SSTF	Survivability Study Task Force
STI	scientific and technical information
STORM	standoff remote mine
SU	setter unit
SWL	Signals Warfare Laboratory
SXTF	Satellite X-Ray Test Facility
TAB	tape automatic bond
TACED	Tank-Appended Crew-Evaluation Device
TACFIRE	Tactical Fire Direction Center
TARADCOM	Tank Automotive Research and Development Command
TARCOM	Tank Automotive Readiness Command
TC	type classified
TDA	Table of Distribution and Allowances
TDD	target detecting device
TDV	technology development vehicle
TECOM	Test and Evaluation Command
TEMPS	Transportable Electromagnetic Pulse Simulator
TEMSEP	Tactical Environment Multiple Systems Evaluation Program
TIG	tungsten/inert gas
TIWG	Test Integration Working Group
TM	telemeter
TMS	thermomechanical shock
TNF/S	Theater Nuclear Force Survivability
TOA	total obligation authority *or* time of arrival
TOS	Tactical Operations System
TPC	triple-product convolver
TPD	terminal protection device
TRADE	Training Devices
TRADOC	Training and Doctrine Command
TRAPATT	trapped plasma avalanche transit time
TRASANA	TRADOC System Analysis Activity
TRE	transient-radiation effects
TREE	transient-radiation effects on electronics
TRI-TAC	tri-service tactical area communications
TSC	Technology Services Corporation
TSO	time-sharing option
TTAS	table-top artillery simulator
TTCP	The Technical Cooperation Program
TTD	test training device
TWC	transient waveform control
UEJ	unattended/expendable jammer
USAF	US Air Force
USAISD	US Army Intelligence Systems Directorate
USANCA	US Army Nuclear and Chemical Agency
USGS	US Geological Survey
VCSA	Vice Chief of Staff of the Army
VEMASID	vehicle magnetic signature duplicator
VEMPS	Vertical Electromagnetic Pulse Simulator
VMOS	"V" metal oxide semiconductor
VR	vertical recovery

Acronyms and Abbreviations (cont'd)

VSWR	voltage standing wave ratio
WAM	wide-area mine
WP	Warsaw Pact
WRF	Woodbridge Research Facility
WSMR	White Sands Missile Range
WWMCCS	Worldwide Military Command and Control System
XES	x-ray energy spectrometer
XMISR	experimental model ISR
YPG	Yuma Proving Ground

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